

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

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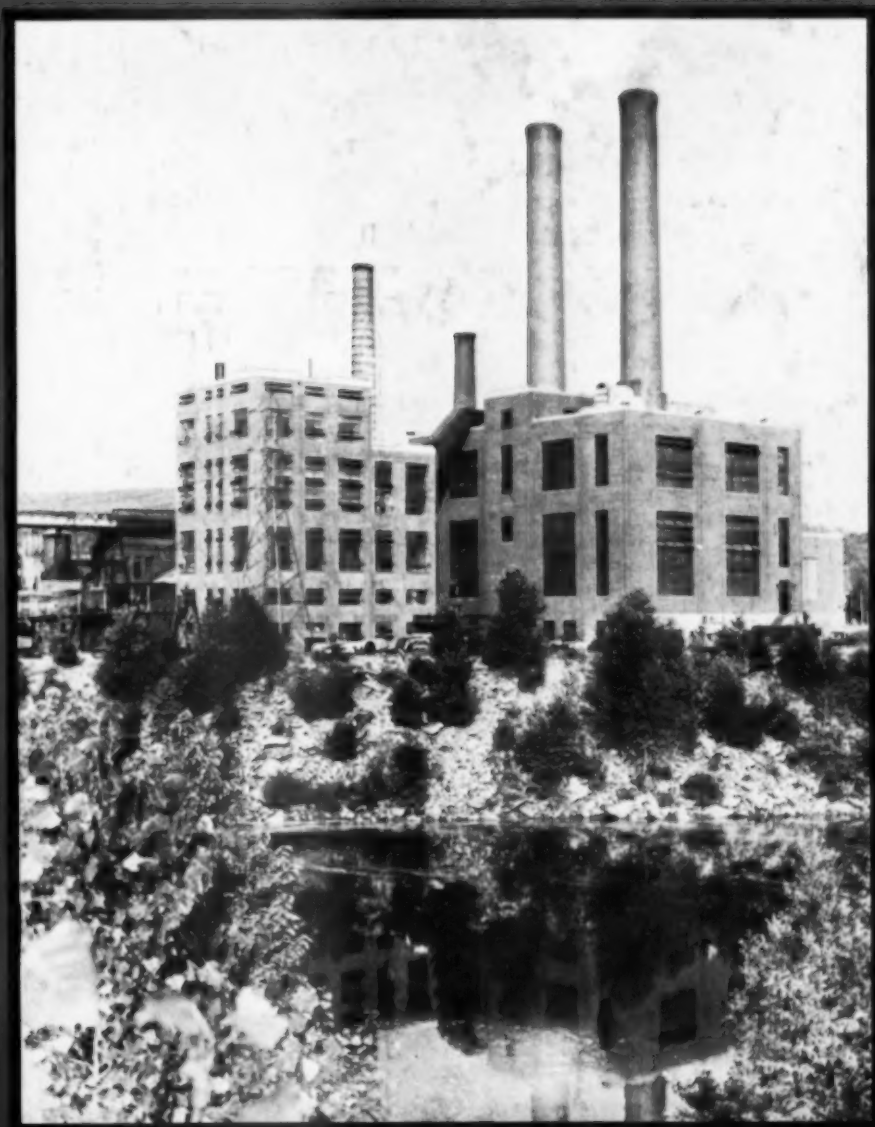


Photo by H. E. Towse
Power Plant of Oxford Paper Company at Rumford, Maine

New 100,000-Kw Steam Power Station at Harnes ►

Control of Fans by Adjustable-Speed Fluid Drives ►

Factors in Selection of Boilers ►

Recent C-E Steam Generating Units for Utilities

DUNKIRK STEAM STATION

BUFFALO NIAGARA ELECTRIC CORPORATION

THE C-E Unit, shown here, is one of two duplicate steam generating units now in process of fabrication for the Dunkirk Steam Station of the Buffalo Niagara Electric Corporation of Buffalo, New York.

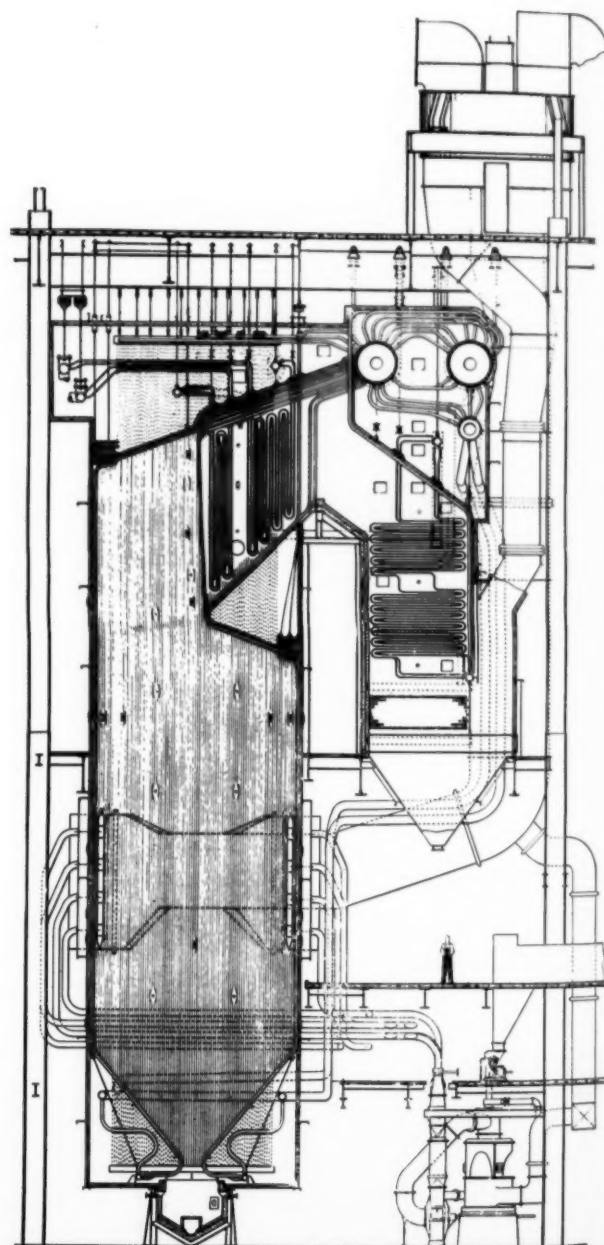
Each of these units is designed to produce, at maximum continuous capacity, 670,000 lb of steam per hr at 1492 psi and 1000 F at the superheater outlet and to reheat 585,000 lb from 701 F to 1000 F and deliver it at 389 psi at the reheater outlet.

The units are of the radiant type with a reheater section located between two stages of the primary superheater surface. A finned tube economizer is located below the rear superheater section, and regenerative air heaters follow the economizer surface.

The furnaces are fully water cooled, using closely spaced plain tubes throughout. They are of the basket-bottom type, discharging to sluicing ash hoppers.

Pulverized coal firing is employed, using bowl mills and vertically-adjustable, tangential burners.

B-319



Combustion Engineering-Superheater, Inc.

A Merger of COMBUSTION ENGINEERING COMPANY, INC. and THE SUPERHEATER COMPANY

200 MADISON AVENUE, NEW YORK 16, N. Y.

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

Vol. 21

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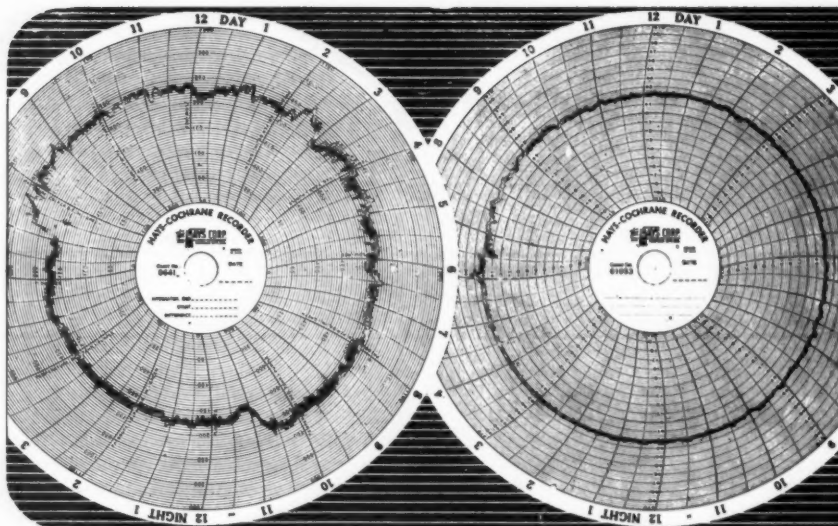
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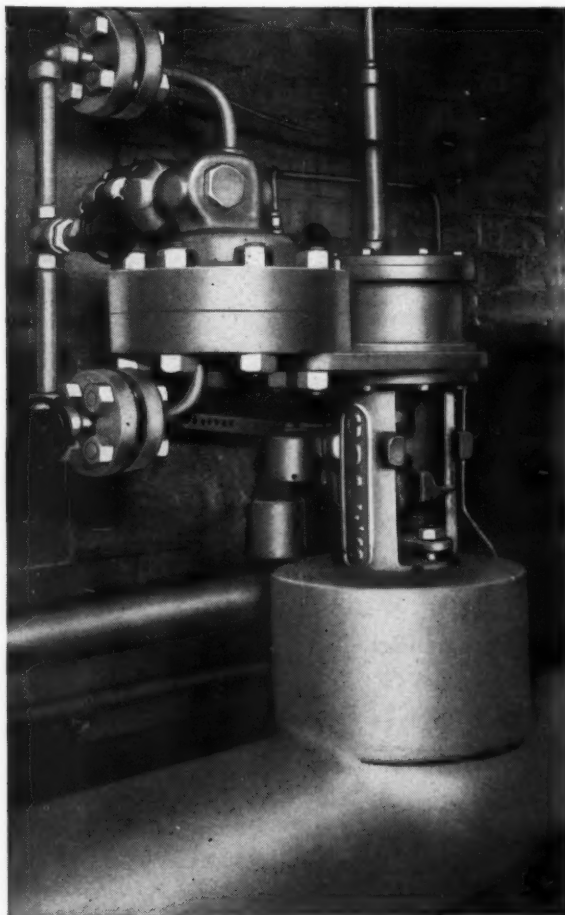
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COMBUSTION

Editorials

Omission of the Degree

A recent issue of *The Professional Engineer*, official publication of The New York State Society of Professional Engineers, commented upon the fact that so few of those qualified are in the habit of placing "P.E." after their signatures.

This is true not only of the licensed professional engineer's designation, but of engineering degrees in general. It is in contrast to practice abroad, particularly in Germany and England where even engineering society membership is usually indicated in published signatures, in addition to engineering degrees.

Few medical men would think of omitting "M.D." after their names. Why do engineers? Can such omission on the part of engineers be attributed to modesty, to lack of appreciation of a degree or to just plain indifference?

Beyond the Control Room

Picture yourself in the control room of a post-war central station. As someone attempts to explain the functions of this mechanical and electrical labyrinth, what thoughts come to your mind?

If a layman, you will undoubtedly be awed by the vast array of instruments and control devices and wonder how any human being can understand their operation. If you are a plant design engineer, the reality of the scene will be tinged by recollections of vexing conferences, frantic expediting and complex plans changed time and again. If you are an equipment designer, you probably will be anxious to know how your specialty is incorporated in the centralized control system and how well it functions. Perhaps you are a manufacturer's representative, in which case you will unconsciously plan how to use the installation to impress prospective customers. Or you may be an architect and find that the lighting and acoustical treatment of the control room are of special interest.

But isn't it possible that you have overlooked something? Here in your very midst the equivalent of 100,000 horses, or more, is being controlled by a mere handful of men. They are doing this without fanfare in a calm, matter-of-fact manner, and they are working in an atmosphere as clean as your home and no more noisy than the average office. What a contrast this is to the traditional conception of a power plant as a grimy,

dusty arena of discordant sounds and toilsome physical exertions.

How has this transformation taken place? As you leave the control room, just consider the amount of teamwork and cooperation and know-how that modern science and engineering have channeled to make the accomplishment possible.

The Three-Day Mining Week

Thus far the so-called stabilization dictum of John L. Lewis, imposing a three-day coal mining week, seems to be affecting producers and carriers more than users, as may be judged from the recent testimony of prominent coal men before a Senate Committee. This may be ascribed to the relatively large stocks of coal on hand at the beginning of the curtailed output, a more or less mild industrial recession and to the seasonal factor. However, if the restriction continues for a considerable period, it is certain to adversely affect consumers as well as the operators. In fact, reports from some sources indicate a dwindling of coal stocks to an uncomfortable degree.

As is well known, Mr. Lewis' strategy was to reduce coal stocks to the point where he would be in a more advantageous position to enforce new demands through threat of a strike, notwithstanding that in the interim his miners are being penalized through reduced earnings and smaller contributions to their welfare fund; both of which he hopes to recoup by the terms of the new contract.

The present curtailment means increased production costs by burdening a three-day output with full overhead and fixed charges. This, and the anticipated terms of a new contract when negotiated, are most likely to bring about a substantial increase in prices to consumers and will thus place coal at a further disadvantage in competition with other fuels.

Whether anything tangible comes out of the present Senate Committee hearings will depend to a considerable extent upon public reaction. If a large number of consumers were to make their opinions felt before it is too late, they would likely accomplish more than the testimony of coal industry representatives. It was encouraging, however, to note that Thurman Arnold, former trust buster and ardent New Dealer, has come out strongly for restrictive legislation to protect the public interest against such a labor monopoly as is exercised by Mr. Lewis.

New 100,000-Kw Steam Power Station at Harnes, Pas de Calais, France

This is a mine-mouth plant of 100,000-kw capacity in two units, serving both a mining load and a transmission network. Steam is supplied at 850 psig, 900 F, by four 375,000-lb per hour pulverized-coal-fired boilers and the fuel averages 8400 Btu per lb with an ash content of 35 per cent. Cooling towers are employed for the condensing water. Both the design and the equipment are completely American.

COAL is the keynote of the new Harnes Power Plant in the heart of the coal mining area of northern France not far from the Belgium border. Primarily the plant will serve a 40,000-kw coal mine load and its surplus power will feed into the Paris network. Like most mine-mouth power plants, Harnes will burn refuse coal having an average heating value of about 8400 Btu per lb and an ash content of around 35 per cent. It takes over the load of the old 80,000-kw station which was built immediately after the first World War.

By S. WEINER* and E. ASLAKSEN†

Situated near a canal whose water is inadequate for condensing purpose, the plant employs cooling towers and will normally use treated well-water makeup for other requirements. Fig. 2 shows the rear of the new plant with the old plant in the background beyond the cooling towers and water treatment plant.

A firm supply of power for the mines was the criterion for the design and selection of equipment. Two units of 50,000 kw nominal rating are installed to assure that supply and normally contribute a sizable block of power to the transmission network.

Gibbs & Hill, Inc., New York, in coordination with the engineering department of the Houilleres du Nord et du Pas de Calais, France, started the design of the power plant in the fall of 1945; and the major equipment was ordered by the end of 1945 by the French Supply Council in accordance with specifications prepared by Gibbs & Hill, Inc.

* Mechanical Engineer, Gibbs & Hill, Inc.
† Electrical Engineer, Gibbs & Hill, Inc.

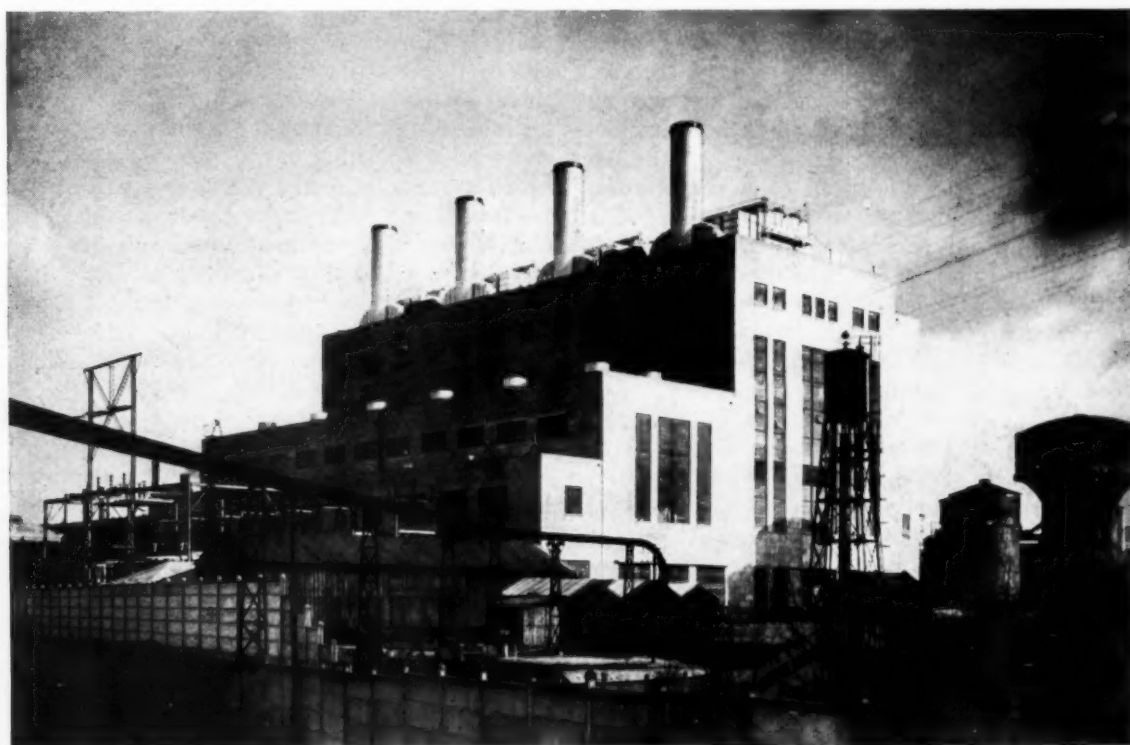


Fig. 1—Harnes Power Plant of Houilleres du Nord et du Pas de Calais



Fig. 2—New and old plants with cooling tower structures

The new plant was located immediately to the west of the old plant to obtain an economical connection to the existing 16,200-volt mine network, a convenient extension to existing rail facilities, and to avoid the emission from the old stacks in prevailing winds.

Fig. 3 is a section through the plant.

General Features

Each turbine-generator is supplied by two boilers because of the unusually high ash content of the coal and its probable adverse effect on their availability, although three boilers have sufficient capacity to carry the two units at full load. Each boiler has a continuous capacity of 375,000 lb per hr, which assures the mine load with one boiler and the other turbine-generator out of service. Normally two boilers supply one turbine-generator independently on a unit system. However, interconnections are provided so that one boiler of one unit may supply the other unit when the deaerators of the two systems are paralleled at a common fixed pressure.

Since the cooling water to the towers is entirely under pressure, the lower floor is just above grade and the operating floor thirty feet above. The two turbine-generators are set with their axes parallel to the length of the turbine room. A feature of the plant arrangement is the control room on the operating floor in the center of the plant in a bay between the turbine room and boilers. Control of boilers is on one side and that of the turbines and electrical switching on the other side of this room. Auxiliary 3000- and 400-volt switchgear is on the lower floor level. Boiler feed pumps are located in this bay on the operating floor on both sides of the control room and there is no division wall between turbine and boiler rooms. Deaerating and high-pressure heaters are also in

this bay above the pumps and control room. Fans are located above the boilers and electrostatic precipitators overhead on the roof. Coal bunkers, feeders and pulverizers are in an aisle on the far side of the boilers. The 16,200-volt switchgear, offices and other general facilities are located in a low bay on the opposite side of the turbine room. The outdoor step-up substation is just beyond this bay. The cooling tower is on the side of the plant where it is sheltered the least and where prevailing winds will not convey moisture-laden atmosphere into the plant.

The two Westinghouse 3000-rpm turbine-generators are of the tandem-compound, double-flow, impulse-reaction type, nominally rated at 50,000 kw, with 16,200-volt, 3-phase, 50-cycle generators rated 50,000 kw, 0.8 pf at $\frac{1}{2}$ psi hydrogen pressure, and 62,500 kw, 0.87 pf at 15 psi hydrogen pressure. A 4000-kw, 0.8-pf, 3200-volt, 3-phase, 50-cycle air-cooled auxiliary generator is also direct-connected to each unit. The exciters are separately motor-driven.

Throttle steam conditions are 850 psig, 900 F, and the exhaust is nominally 2 in. Hg back pressure. Steam is extracted at five points for feedwater heating in the regenerative cycle; namely, the 5th, 11th, 17th and 23rd stages of the high-pressure cylinder and the 4th stage of the low-pressure cylinder.

Plant Heat Balance

The heat balance for one unit is shown in Fig. 5. The two high-pressure stages are each equipped with two heaters, one for each boiler and the other stages, with one heater. At 62,500 kw output and 2 in. Hg back pressure, the turbine heat rate is calculated at 9522 Btu per kw-hr, and the station heat rate under the same conditions at 12,050 Btu per net kw-hr.

The high-pressure heaters are horizontally mounted and equipped with desuperheating sections, No. 5 having a negative terminal difference of 3 deg F and No. 4 of 0 deg F. Heater No. 4 is equipped with an integral drain cooler with a terminal difference of 12 deg F. The low-pressure heaters both have a 5 deg F terminal difference and have separate drain coolers with 12 deg F and 5 deg F terminal differences, respectively, for Nos. 2 and 1, the latter draining to the condenser. No. 2 heater is vertically mounted on the operating floor and No. 1 is horizontally mounted in the neck of the condenser. All heater drains are cascaded and no drip pumps are employed. Also, the physical arrangement is such that all heaters, except No. 2, cascade at very low loads.

The middle (No. 3) heaters are tray-type "zero"-oxygen deaerators with conventional storage and baffled suction to avoid vaporizing in the feed pumps upon sud-

den decrease in load. These heaters will normally be floated at extraction pressure and at high loads condensate from the hot-well pumps will be boosted by supplementary pumps. Provision is made for operating the deaerators at fixed pressure in parallel when boilers of one unit are supplying steam to the other unit.

Due to the high ash content of the coal and potential loss of condensate because of heavy soot blowing, a spare evaporator common to both units is provided, as well as the individual evaporators for each unit. These evaporators are supplied from a hot-process softener and vapor is discharged to the deaerators.

Condensate is stored in concrete tanks located under the basement floor and specially painted to avoid pickup of silica. Low hotwell level induces condensate from storage and high hotwell level discharges condensate from the pumps to storage. Low deaerator level actuates

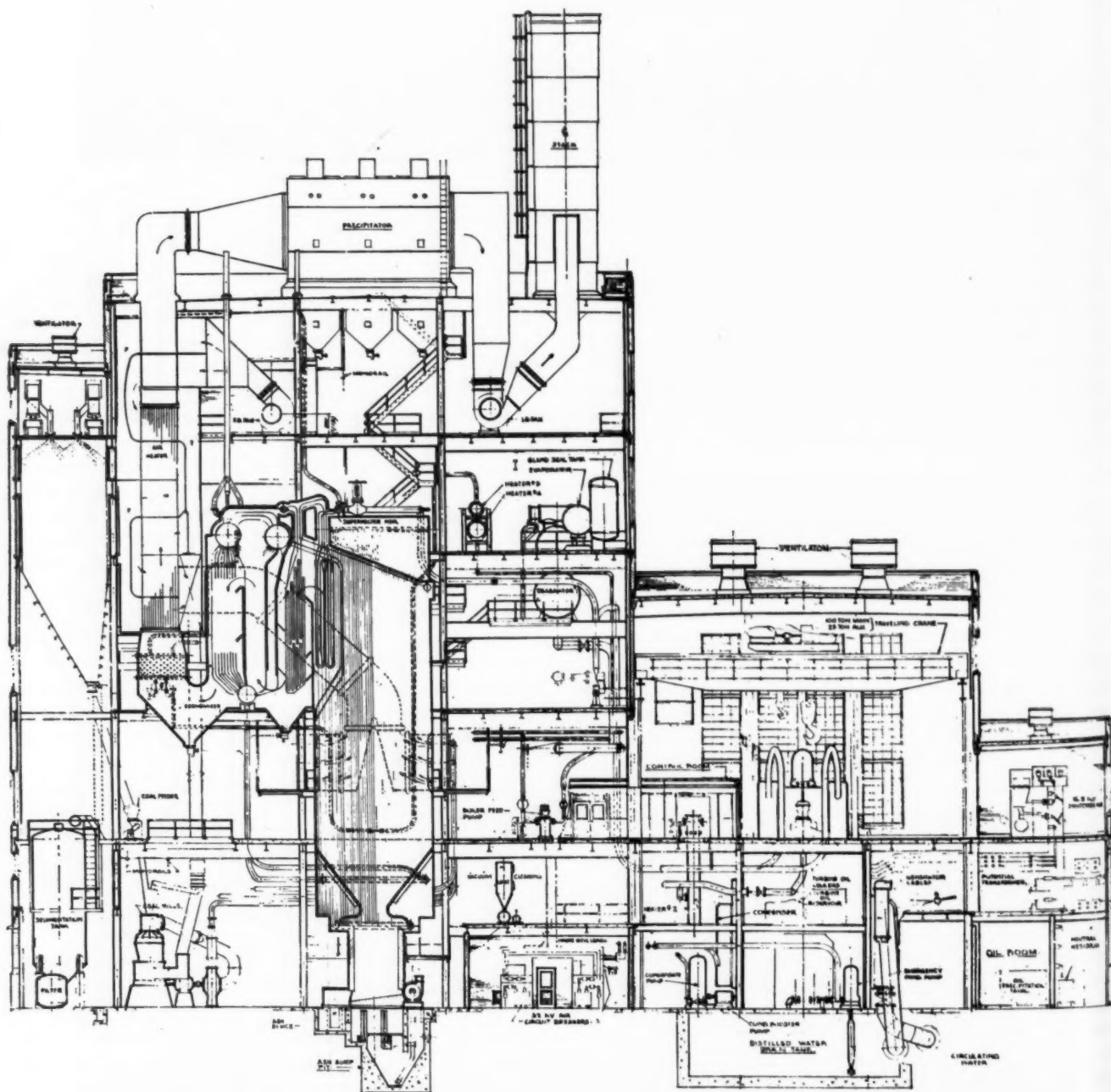


Fig. 3—Section through Harnes Power Plant

an emergency pump supplying condensate direct from the tank.

The Westinghouse condensers have 45,000 sq ft of $7/8$ in. tubes, 24 ft long, and are of the two-pass radial-flow type with divided water boxes. In order to maintain minimum height from basement to operating floor, the condenser is provided with a shallow hotwell and vertical hotwell pumps. Each condenser is supplied by two vertical circulating pumps of the axial-flow type delivering a total of 45,000 gpm from a separate building at the end of the cooling tower. To meet French freight clearances, it was necessary to ship the condensers in 13 pieces.

The induced-draft cooling tower has capacity to reduce the temperature of 90,000 gpm from 100 F to 81 F, or within 15 deg F of a 66 F wet bulb. It consists of two

twelve tangential coal burners equipped with remote manual tilt control. The furnaces were designed for a heat release of 17,600 Btu per cu ft per hr at maximum load and the heat available is 88,500 Btu per sq ft of black projected area per hour. An outstanding feature of the boilers is their width and consequent low gas velocities to avoid tube cutting from the unusually high dust loading. Reintroduction of ash to reduce carbon loss was considered and rejected due to the excessive dust loadings and anticipated low carbon loss with tangential firing. Because of the low sulfur content of the French coals, exit gas temperature is 275 F and the calculated efficiency is 86.7 per cent at maximum rating.

Gas is used for lighting off and bringing the units up to pressure. It will also supplement the pulverized coal at very low loads.

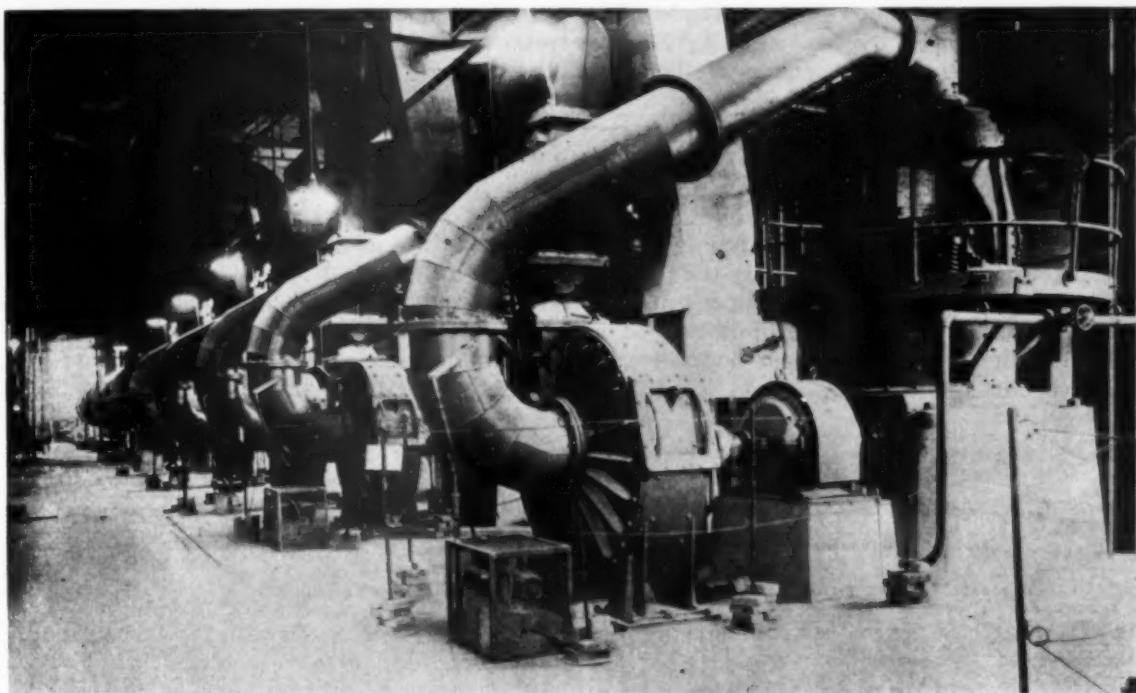


Fig. 4—View of pulverizers

banks, back to back, of 11 cells each 31 ft high and occupying a space 352 ft long by 64 ft wide, with a 6-ft-deep basin (See Fig. 2). The tower basin and valves are divided longitudinally into two sections to accommodate each condenser as a unit and to facilitate cleaning of the basins with only one unit out of service. The fans and interior redwood structure were supplied by Foster Wheeler and the concrete frame and basin were designed and constructed in France.

Steam Generating Equipment

The four Combustion Engineering-Superheater steam generators each have a steaming capacity of 375,000 lb per hr at 885 psig, 900 F. They consist of a three-drum bent-tube boiler with dry-bottom water-walled furnace, horizontal fin-tube economizer, vertical two-section tubular air heaters, and two-stage superheater with bypass-damper temperature control, supplemented by vertically adjustable tilting burners. Each unit is direct-fired by three C-E Raymond bowl mills supplying

Each boiler is equipped with two forced- and two induced-draft fans. The forced-draft fans have inlet vane control and are driven by two motors at 1500 and 1000 rpm. The induced-draft fans also have inlet lower control and are driven by two-speed motors at 1000 and 750 rpm. The low speeds of the fans are employed for all normal conditions and the high speeds only in emergencies. The induced-draft fans of each boiler discharge the gases to a 10-ft-diameter steel stack, extending 50 ft above the roof.

The combustion-control system is of the Leeds & Northrup air-electric metered type. Speed of the coal feeders and position of the induced-draft-fan inlet dampers are regulated from the pressure-governed master control, while furnace suction is automatically maintained by regulation of the forced-draft inlet vanes. Both boilers normally supplying a turbine may be paralleled from one master controller or all four may be paralleled from either master controller. The output of one or more boilers may be adjusted with respect to the

others, or any or all of the boilers may be operated on base load independent of steam pressure but with automatic control of fuel-air ratio and furnace suction. The number of mills in operation and the speed of the fans are at the discretion of the operator who is warned by alarms when these equipments are limited. Interlocks are provided to open and close vanes and dampers when fans are taken in or out of service.

Each pair of two boilers is served by three boiler feed pumps, two motor-driven and for standby, one steam-turbine-driven pump. Each is of sufficient capacity and head to take care of one boiler under all conditions. The pumps are of the opposed-impeller volute type and are driven at 3600 rpm by the motors through step-up gears and directly by the steam turbine.

Coal and Ash Handling

Coal is brought in small freight cars from nearby mines to the old plant, where it is blended and stored in several bins. From these bins it is fed by two 150-tons-per-hour conveyors through trippers to the bunkers of the new plant. Each boiler has bunker storage of 600 tons or more than enough for twenty-four hours' operation at maximum rating.

Because of the high ash content of the refuse, a system was required which would collect and unload into cars a maximum of 1000 tons of ash a day with a minimum of maintenance. A review of ash-system costs in the United States indicated that the coarser boiler-hopper ash and pulverizer rejects should be handled hydraulically and the fine ash from the precipitators, soot hoppers and stack by a dry-vacuum system.

The hopper ash and pulverizer rejects are sluiced to a sump from which they are pumped to dewatering tanks located over two tracks about 300 ft from the plant. Ash is dumped from these tanks into cars and water is drawn off to a settling and recirculating basin of 270,000-gallon capacity. This is divided into two sections longitudinally, water traveling the length of one section and doubling back the other length to the suction of the recirculating pump. The basin will be cleaned occasionally with a grab bucket operated from a crane on a paralleling track. Pumps supplying water to the dustless unloaders of the dry vacuum system take their suction from the bottom of the basin; hence provide means of continuously deconcentrating fine ash.

Vacuum for handling fine ash from the precipitators and soot hoppers is created by a high-pressure water jet, ash being discharged into bins over the same two tracks as the dewatering bins and unloaded therefrom into cars by conventional dustless unloaders, two per bin. The system is divided into two complete parts with suitable cross-connections, and the hoppers are automatically emptied by a sequential system actuated by loss of vacuum when a hopper is empty.

The dewatering bins each have a capacity of 150 tons and each dust bin a capacity of 215 tons. Each of the four dustless unloaders has a capacity of 30 tons per hour. With a load factor of 80 per cent, and an ash content of 35 per cent, the bottom ash system will be operated about 3½ hours per day and the fly-ash system about 6 hours. The ash pumps are stelled at known points of maximum wear to minimize maintenance.

Both cooling-tower makeup and evaporator makeup

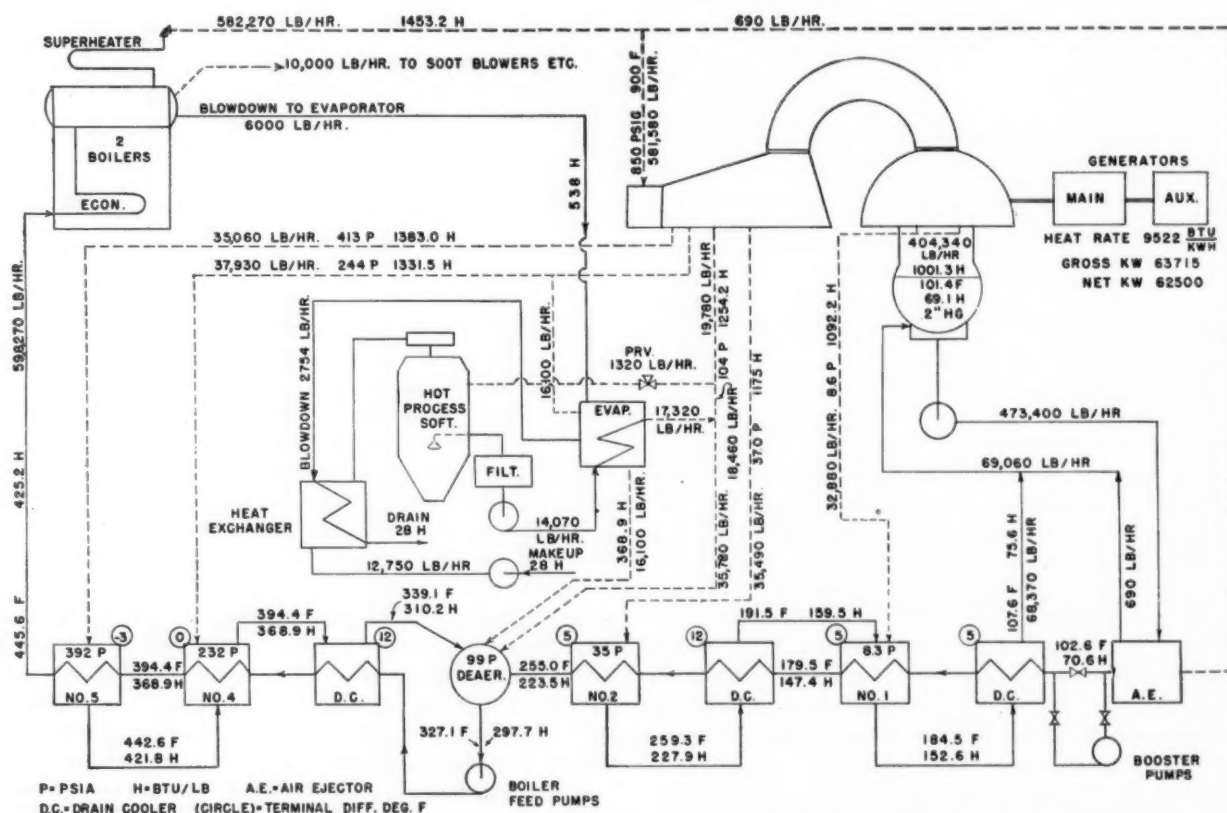


Fig. 5—Heat balance diagram

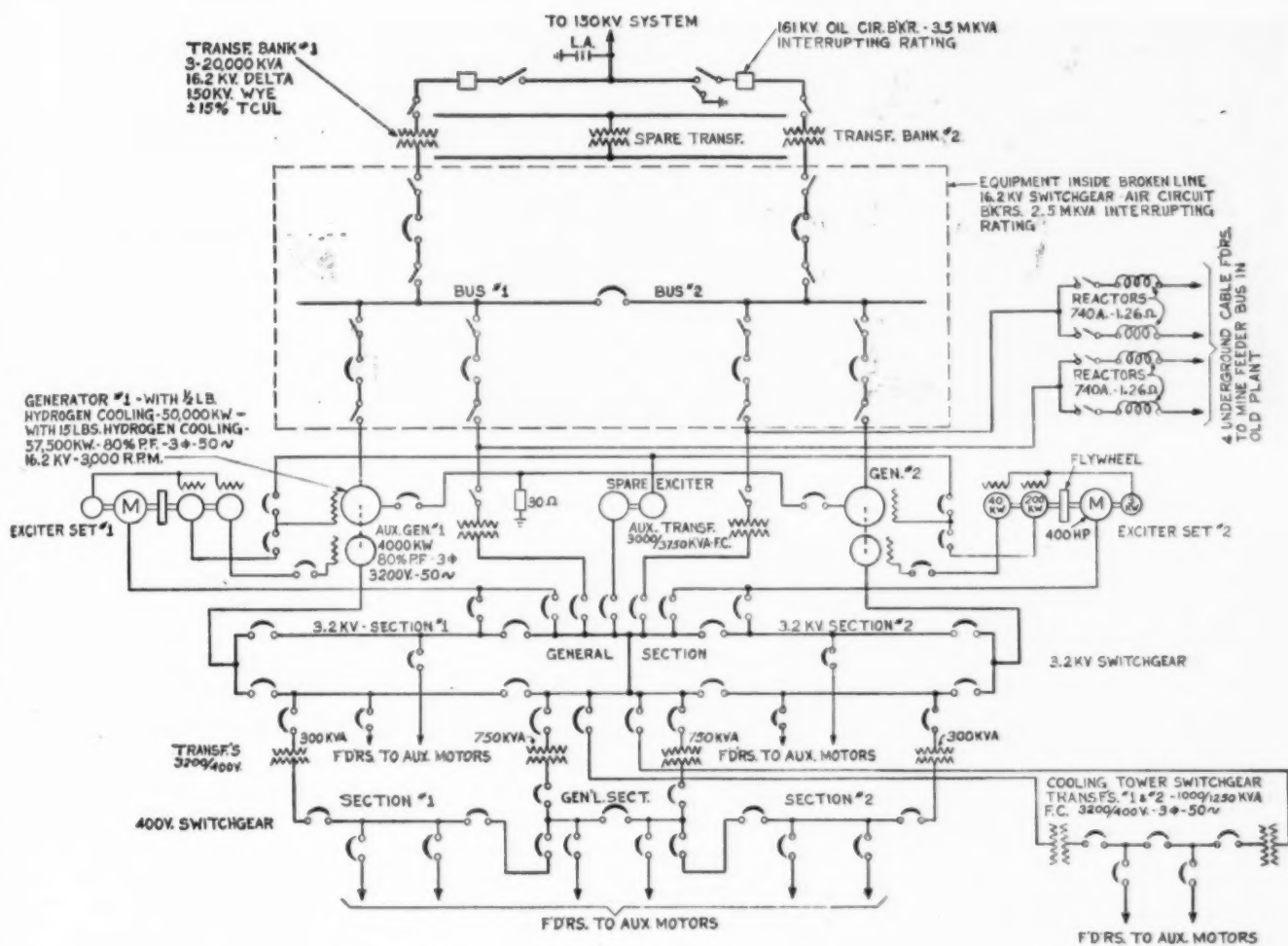


Fig. 6—Principal electrical connections

are taken from wells and stored in a large concrete tank west of the plant. Treatment is by the cold lime process in two spirators, with filtration and storage in a 60,000-gal tank. Water for the cooling tower is fed to the basin and further treated with acid under pH control. That for the evaporators is softened further by a hot-process softener with three filters.

The boilers are treated internally with trisodium phosphate and the evaporators with monosodium phosphate. Sodium sulfite is introduced at the deaerators to eliminate residual oxygen.

The combined maximum output of the two main generators is 115,000 kw of which about 40,000 kw is required for the supply to the local mines. All power in excess of the mine requirements is furnished to the 150-kv transmission network through two banks of step-up transformers. This transmission network supplies power to the mine and industrial area of northeastern France, and it is also interconnected with the power system of Electricite de France.

Electrical System

Four 20,000-kva underground cable feeders are installed to carry the power from the new plant to the mine feeder bus in the old power plant, whence it is distributed over 32 radial feeders to the mines at 15,750 volts.

A maximum short-circuit of 500 mva was permissible at the old plant bus, whereas the available short-circuit on the generator bus in the new plant was found to be over 2000 mva. Reactors were therefore installed on the four feeders, and, to compensate for the voltage drop, the generator voltage in the new plant was set at 16.2 kv, plus or minus 5 per cent. This voltage is adjusted with varying loads to maintain a constant potential of 15,750 volts on the old plant bus. Any number, from one to three, of the feeders may be placed in service to meet the mine load conditions. A fourth feeder will always be a spare.

The 16.2-kv switchgear is of the metal-enclosed, cubicle type with pneumatically operated 17-kv, 5000-amp, three-pole, air-blast circuit-breakers, with an interrupting capacity of 2500 mva. It is arranged in two bus sections, each with a generator breaker, a step-up transformer breaker, and a breaker for a combined pair of mine bus feeders and a 3000-kva (3750-kva with fan cooling) general auxiliary transformer.

Each of the two step-up transformer banks consists of three single-phase, 20,000-kva transformers, 16.2/86.6 Kv-150,000 Y volts, provided with plus or minus 15 per cent full capacity tap changers under load in +8 and -8 steps. The tap changers are remote-controlled, singly or as a bank, from the main control board. This wide range

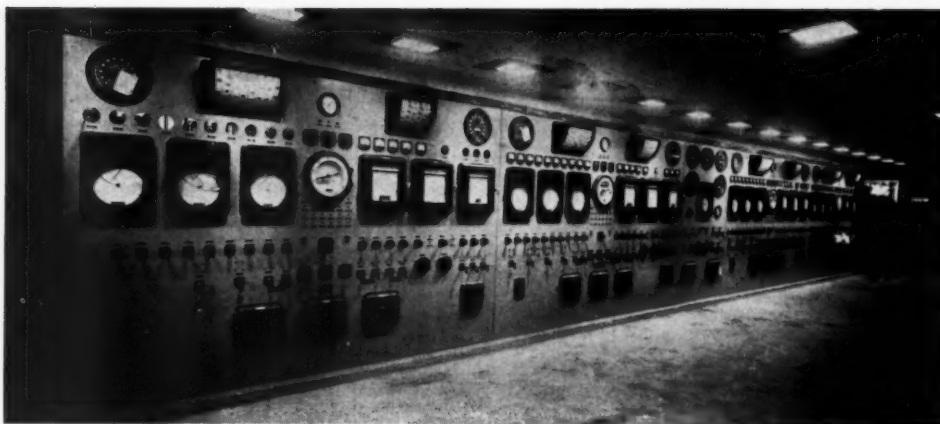


Fig. 7—The main switchboard

of taps was provided to adjust for the variations in generator voltage as stated above, and for regulation on the 150-kv transmission system.

A seventh spare transformer is located between the two banks, and the high and low voltage buses are so arranged that it can be connected to replace any one of the other transformers without moving it from its permanent position. The transformers connect on the 150-kv side through oil circuit breakers to a common outgoing transmission line. These circuit breakers are pneumatically operated and have an interrupting capacity of 3500 mva.

In order to achieve a conservative design for the turbine-generator units, it was decided to provide a separate motor-driven exciter unit for each machine rather than furnish them with generators and exciters all on one drive. The exciter units consist of a 3.2-kv, 400-hp, squirrel-cage motor, with a large flywheel; a 200-kw, 250-volt main-generator exciter; a 40-kw, 250-volt auxiliary-generator exciter; and a common 3-kw, 250-volt pilot exciter.

Automatic voltage regulators with normal and quick response contacts are provided for both the main and auxiliary generators.

To limit ground-fault currents on the thirty-two low-capacity, 3-conductor underground cable feeders from the old plant to the mines, provision was made for a comparatively high resistance (30 ohms) for the generator neutral grounding. The generator neutrals are each connected to the common resistor through an air circuit-breaker. Only one generator neutral is grounded at any time.

As a result of the low value of ground fault currents, low energy directional ground fault relays are used for all 16.2-kv circuits and equipment in addition to the usual differential and overcurrent relays.

A 3.2-kv, 3-phase, 50-cycle metal-enclosed switchgear is provided for all auxiliary motors of 100 hp or over; and 400-volt, 3-phase, 50-cycle metal-clad switchgear is used for the auxiliary motors of less than 100 hp. Small motors are single-phase type, 115 volts, connected to the lighting source. Both the 3.2-kv and the 400-volt switchgears have drawout-type air circuit-breakers.

The 400-volt auxiliary power system is arranged in a manner similar to the 3200-volt system, and both systems are coordinated so as to provide flexibility and continuity of service.

The Harnes power plant was designed and equipped in accordance with modern American practice, and arranged to insure continuity of operation under adverse conditions. It has created widespread interest among engineers and power plant operators in other European countries, as well as in France, in that it affords an excellent opportunity for observing the latest American methods and equipment.

PRINCIPAL MECHANICAL EQUIPMENT

DESCRIPTION	MANUFACTURER
Air conditioner	Worthington
Ash-handling equipment	Allen-Sherman-Hoff Co.
Blowdown heat-exchangers	Griscom-Russell Co.
Boilers	Combustion Engineering-Superheater, Inc.
Coal-handling equipment	Robins Conveyors, Inc.
Combustion control	Leeds & Northrup Co.
Air compressors and receiver	Joy Manufacturing Co.
Condensers	Westinghouse Electric International Co.
Sample coolers	Bailey Meter Co.
Cooling tower	Foster Wheeler Corp.
Turbine-room crane	Manning, Maxwell & Moore
Ducts and dampers	Connery Construction Co.
Dust collectors	Research Corp.
Evaporators	Griscom-Russell Co.
Forced- and induced-draft fans	American Blower Corp.
Fan drives	Westinghouse
Gages	Manning, Maxwell & Moore
Deaerating heaters	Elliott Co.
F-W heaters and drain coolers	Griscom-Russell Co.
Electric hoist	Shepard Niles Corp.
Hoists and trolleys	Chisholm-Moore Corp.
Insulation	Robert A. Keasbey Co.
Level indicators and level alarms	Energy Control Co.
Gas flow meter	Bailey Meter Co.
Lubricating oils and greases	The Texas Co.
Oil conditioning equipment	S. F. Bowser & Co.
Piping	M. W. Kellogg Co.
Coal piping	Stock Engineering Co.
Boiler feed pumps	Worthington
Chemical feed pumps	Milton Roy Co.
Circulating-water pumps	Westinghouse
Hotwell pumps	Westinghouse
Miscellaneous pumps	Turbine Equipment Co.
Steel stacks and bunkers	Bethlehem Steel Export Co.
Turbine-generators	Westinghouse
Flow control valves	Manning, Maxwell & Moore
Iron and bronze valves	Chapman Valve Mfg. Co. and William Powell Co.
Non-return valves	Edward Valves, Inc.
Pressure-reducing valves	Fisher Governor Co.
Relief valves	Eastern Steam Spec. Co.
Reverse-flow valves	Ruggles-Klingemann Mfg. Co.
Solenoid valves	General Controls Co.
Special valves	Fisher Governor Co.
Steel valves	William Powell Co. and Crane
Water-treating equipment	The Permutit Co.

Volume Control of Mechanical Draft Fans by Adjustable-Speed Fluid Drive

Fluid drive is widely known because of its extensive application in the automotive industry. This article outlines basic principles and explains advantages of adjustable-speed fluid drive for mechanical draft fans in power plant service.

By R. G. OLSON

American Blower Corporation

VOLUME control of mechanical draft fans by variable-speed operation has received wide acceptance during recent years in industrial as well as in utility power plants. Various methods are available for accomplishing variable speed including steam turbines, wound-rotor motors, fluid drives and electric couplings. All of these drives provide wide-range speed regulation and permit the fan to run at speeds to meet the actual boiler requirements, thus greatly reducing erosion in the case of induced-draft fans, and contributing to quieter operation of forced-draft fans. Saving in power over constant-speed operation is also an important consideration, and this item alone is often sufficient to justify the purchase of the variable-speed equipment.

A type of variable-speed drive that has given considerable impetus to the trend toward variable-speed operation of fans is the fluid coupling or fluid drive, as it is more popularly known. It is used in connection with a constant-speed motor, and thus combines the electrical advantages of squirrel-cage motor drive with the operat-

ing advantages of no-load starting and wide-range stepless speed regulation. This device operates on the same basic principle of hydrokinetic power transmission as the well-known hydraulic coupling that has been used for many years for marine propulsion and the automotive fluid drive that has become so popular in American and English automobiles.

In the fluid drive, two radially vaned, dish-shaped members which face each other but are not connected mechanically are attached to the input and output shafts. Light turbine oil is used as the driving fluid. The driving member known as the impeller acts as a centrifugal pump and imparts kinetic energy to the fluid which then drives the driven member or runner as a turbine. In the automotive or constant-speed fluid drive, the unit operates with a fixed quantity of oil retained in the working circuit by means of an enclosing cover or casing which is bolted to the outer flange of the impeller and encloses the back of the runner. An oil seal between the casing and the output shaft prevents leakage.

In the variable-speed fluid drive shown in Fig. 2, the speed of the output shaft is varied by varying the quantity of oil in the working circuit and to accomplish this, a second enclosing cover known as the outer casing is bolted to the impeller flange. Thus, a rotating chamber

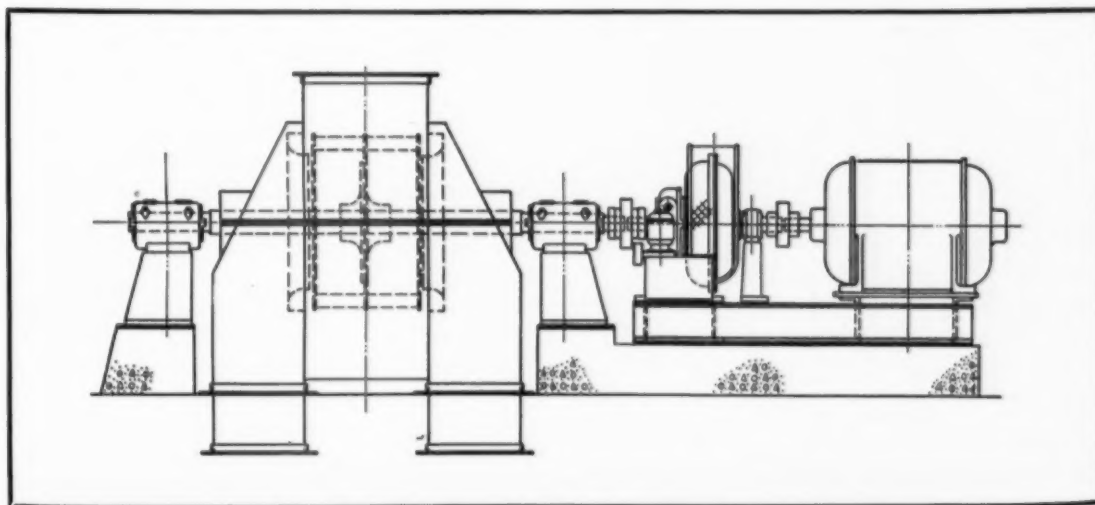


Fig. 1—Induced-draft fan, adjustable-speed fluid drive and constant-speed motor

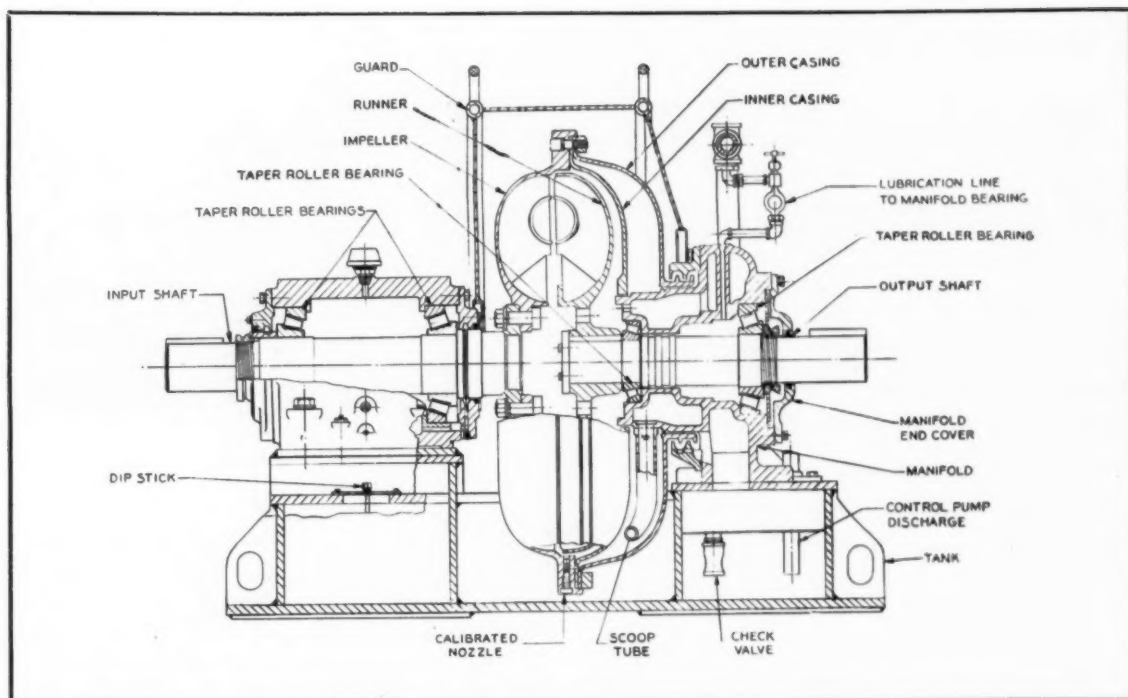


Fig. 2—Type VS adjustable-speed fluid drive

is formed between the inner and outer casings and calibrated nozzles in the periphery of the inner casing permit oil to pass into this chamber from the working circuit. A scoop tube attached to a stationary manifold skims off this oil and circulates it through an oil cooler from which it returns to the coupling through another opening in the manifold. Oil is added or removed by means of a small motor-driven oil pump as an increase or decrease in speed is called for. After the desired speed is established, the pump remains idle and circulation through the oil cooler is maintained by the scoop tube.

With another type of control, the pump runs continuously and diaphragm valves are provided in the piping connecting the pump suction and discharge to the coupling manifold. As changes in speed are called for, the

automatic control causes one valve or the other to open, and after the new condition has been satisfied, both valves remain closed and the pump returns the oil to the sump tank or reservoir through a relief valve. The pumps are of the positive displacement type and operate at a pressure of about 10 to 15 psi. The pump motors range from $\frac{1}{3}$ hp on a fluid drive to transmit 150 hp, to 3 hp on a unit transmitting 2000 hp.

Another type of adjustable-speed fluid drive known as the scoop control type and shown in Fig. 3 is built in ratings from 1 to 200 hp. Idle oil not in the vortex between the impeller and runner is stored in a rotating reservoir or casing which forms a part of the coupling. Centrifugal force maintains the oil in the casing in an annular ring. To fill the vortex, the movable scoop tube is immersed in

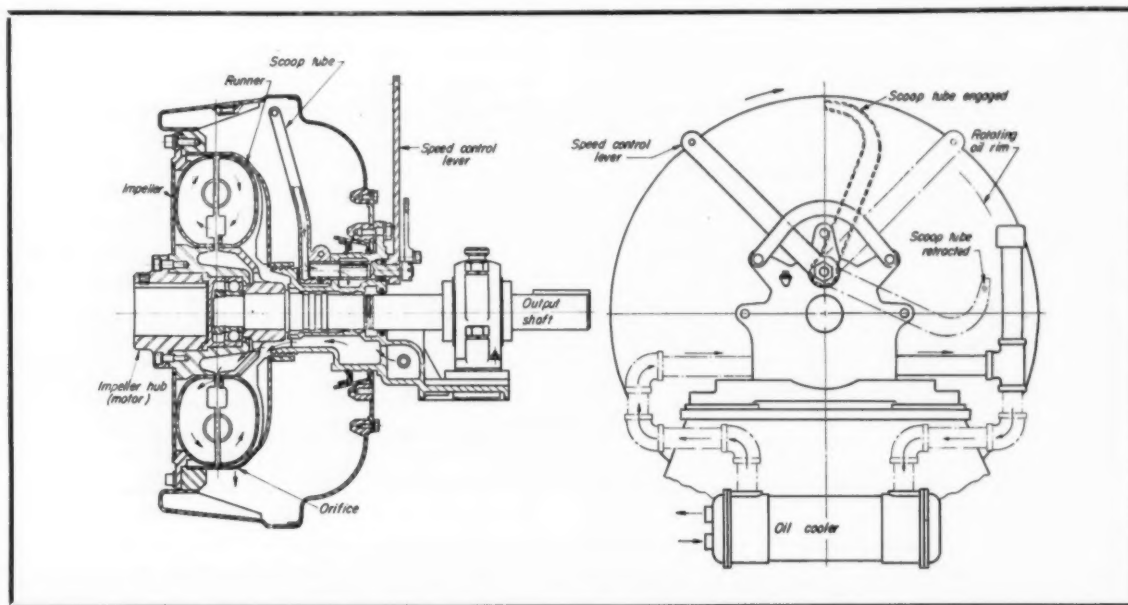


Fig. 3—Type SC scoop-control fluid drive

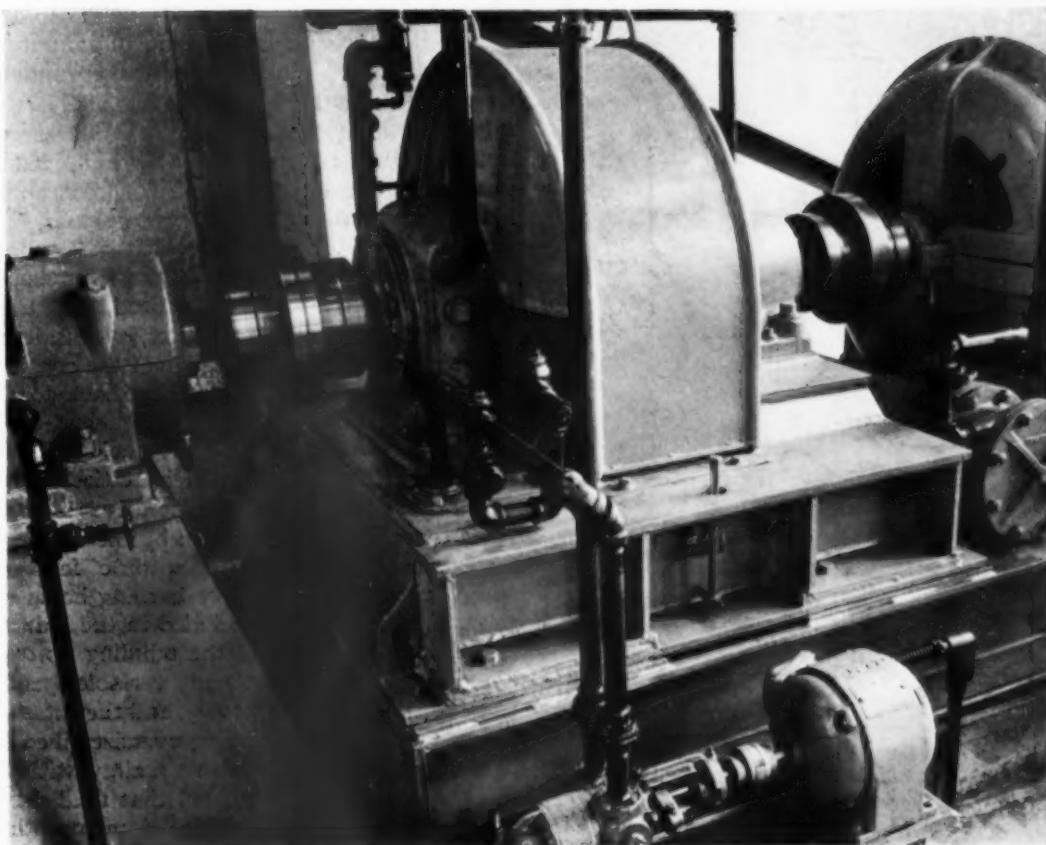


Fig. 4—Fluid drive application to chemical recovery unit in paper industry

the oil ring; it then picks up the oil and forces it outside through a cooler and back into the working circuit. A continuous stream of oil leaves the vortex through calibrated orifices in an inner casing and enters the outer casing where it is again picked up by the scoop tube and circulated. The end view of Fig. 3 shows how it is possible to vary the position of the scoop tube and thus adjust the oil quantity to any desired level by moving the external speed control lever. By attaching a power cylinder, diaphragm operator or damper motor to this lever, the drive is suitable for automatic control.

Fig. 4 shows a variable-speed fluid drive and a 300-hp, 900-rpm motor used for driving an induced-draft fan in connection with a black-liquor-fired boiler in a paper mill. The fluid drive which is under automatic control permits the fan to operate at the required speed to meet boiler requirements. The control is of the reversible pump type, and the small motor driving the pump, shown in the foreground, is energized to operate in one direction or the other as an increase or decrease in speed is called for. The oil cooler is shown between the motor and the fluid drive.

A large number of outdoor and semi-outdoor power plants have been built in recent years, and Fig. 5 shows an induced-draft fan and fluid drive installed in connection with such a plant. The control is of the continuous-running pump type, and the oil cooler is of the conventional shell and tube type with water as the cooling medium. Aside from certain precautions that must be taken to prevent freezing of the automatic control air lines and to drain water and oil lines when a shut down is required in extreme weather, operation of this equipment out-of-doors has proved satisfactory. A roof over the equip-

ment is provided to keep rain from entering the air heater through the forced-draft fan which is located immediately back of the induced-draft fan motor.

In some outdoor installations of fluid drives where cooling water is not available, air-cooled oil coolers have been used. In the case of forced-draft drives, the cooling sections can be located in the fan inlet boxes, while on

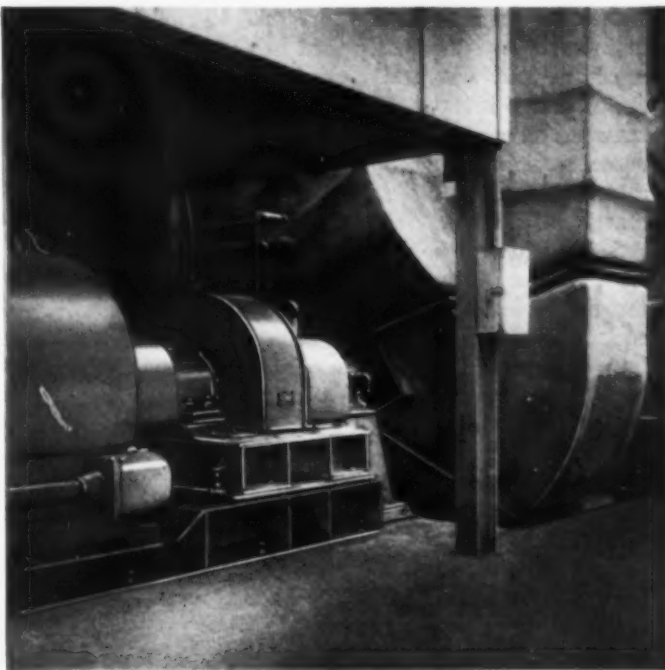


Fig. 5—Semi-outdoor industrial power plant having fluid drive on induced-draft fan

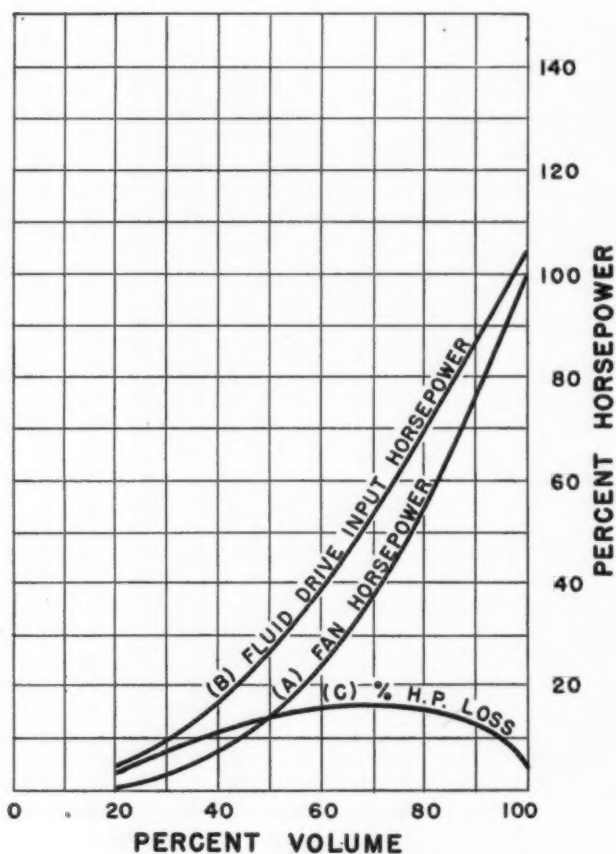


Fig. 6—Curves showing performance of induced-draft fan and adjustable-speed fluid drive

induced-draft drives, cooling units similar in appearance to industrial unit heaters with motor-driven fans have been used.

The fluid used in variable-speed fluid drives is light turbine oil, having a viscosity of 150 Saybolt seconds at 100 F. To simplify inventory, the oil employed for the main turbines is normally used in the fluid drives. The recommended operating temperature of oil entering the oil cooler is 180 F. Local conditions govern the period between oil changes, but in general, annual replacement or centrifuging is recommended. The quantity of oil required in the units shown in Figs. 4 and 5 is approximately 30 gallons.

Like other variable-speed drives, including wound-rotor motors, in which the torque input is equal to the torque output, the efficiency of the fluid drive is roughly equal to the per cent speed, or ratio between output and input speeds. Fixed losses such as windage and bearing friction amount to $1\frac{1}{2}$ to 2 per cent so that at top speed where the slip is $2\frac{1}{2}$ to 3 per cent, the efficiency is 95 to 96 per cent.

The curves in Fig. 6 represent the performance of a fluid drive in connection with a typical induced-draft fan. Curve A shows the power taken by the fan as the volume is varied from 100 per cent down to 20 per cent of design requirement. Curve B shows the power input to the fluid drive, while Curve C shows the difference between Curves A and B and represents the loss of power which has to be dissipated by radiation and in the oil cooler. It will be noted that the maximum loss occurs at

about two-thirds volume and amounts to about 17 per cent of the power required at maximum output.

To take care of leakage, dirty boilers and other contingencies, it is customary to include large factors of safety in the specified volume and pressure for which induced-draft fans are selected. This means that it is possible to operate these fans at speeds appreciably below maximum speed with a resulting saving in power and maintenance which it is difficult to take into consideration in the evaluation at the time of purchase. When a fan is operated at constant speed, and the volume is controlled by dampers or vanes, a considerable portion of the effective operating range of the control frequently has to be used up in dampening back to the specified volume and resistance.

One effect of the safety factors included in fan selection is to increase the amount of heat that has to be dissipated by hydraulic and electric drives, and this fact has to be taken into consideration by the designing engineer. An extreme case is the application of fans and variable-speed drives to black liquor burning boilers where large safety factors must be included in the induced-draft fan selection to take care of the building up of deposits on the fan blades. A great many variable-speed fluid drives have been used in this service, and the extra heat dissipation is handled by employing oversize oil coolers.

Although this article deals mainly with fan applications, it should be mentioned that fluid drives are used for the variable-speed drive of many other types of machines including black liquor and wood stock pumps, water-circulating pumps, coal hoists, ball mills, conveyors and so forth.

A recent development is a totally enclosed unit used for the variable-speed drive of 3600-rpm boiler feed pumps. In this application feedwater flow is controlled by regulating the speed of the pump through the fluid drive and the control is normally accomplished without the use of supplementary regulating valves. These units are built in three sizes covering a range from 300 hp to 2500 hp.

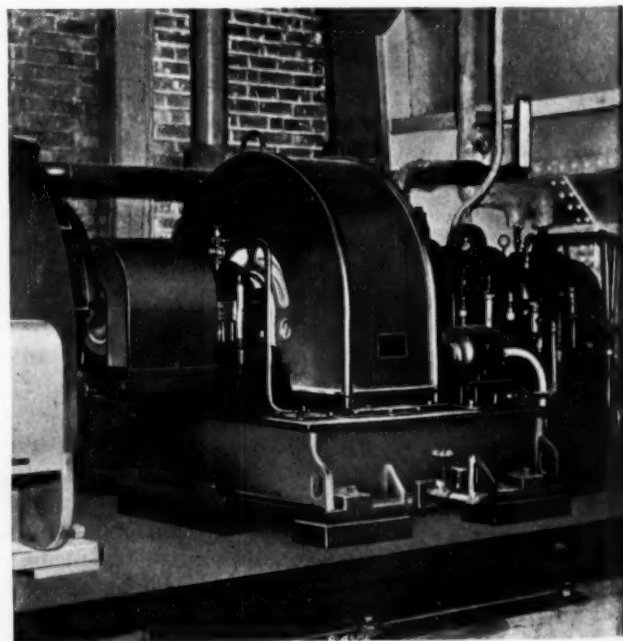


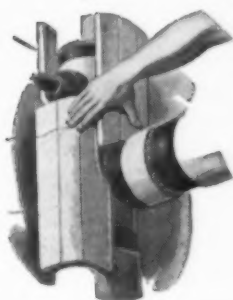
Fig. 7—Type PE fluid drive and 700-hp, 1200-rpm motor driving induced-draft fan in utility power plant

HOW WOULD YOU INSULATE THIS FLANGED FITTING?

4" line requires 85% Magnesia 2" thick on all surfaces, including fittings. Which form of insulation is best for the flanged fitting shown here?



☐ 85% Magnesia cement built up to a total thickness of 1 1/2", then 1/2" asbestos cement applied in two coats.



☐ 85% Magnesia block, carefully fitted, wired in place and finished with asbestos cement.



HERE'S HOW AN ARMSTRONG FOREMAN DID IT:

Whether to use block insulation on a fitting, or to cover it with built-up cement, is a decision that is usually left to the foreman on the job. Both methods are widely used, but the correct choice depends mainly upon the size of the fitting. In the case outlined above, the Armstrong foreman directed his workmen to use method No. 2. For fittings on pipe lines 4" and larger, this method is always more satisfactory. It is faster than laboriously building up the fittings with multiple layers of cement. Also, it eliminates the shrinking and resultant cracking that occurs when built-up cement is used to insulate a fitting of this size.

On pipe sizes smaller than 4", a neat, efficient job can often be done with cement. However, the size and complexity of the fitting must be taken into consideration, and the most satisfactory method selected for the insulating job at hand.

How well the foreman makes his decision can affect the final appearance and efficiency of every insulation job where covering a fitting is called for in the specifications.

Foremen on Armstrong jobs, as well as Armstrong's own construction superintendents and sales engineers, are trained to make the right decisions. There's no blind rule of thumb. When you call upon Armstrong's Contract Service for heat insulation, your needs, and the requirements of your job, determine the methods used.

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European Experiences with Feedwater Treatments

THE following notes are from a summary of a lecture delivered by Dr. Arthur G. Splittgerber, well-known German chemist, last February before representatives of the Steam Users' Association. Although dealing largely with continental practice, they are believed, in many respects, to have wide application.

Reduction of Silicic Acid in Feedwater

Hitherto the methods generally available have been treatment with magnesium oxide and lime at high temperature, or evaporation.

The first of these methods is rather troublesome in practice, and the second, though often excellent in results, is sometimes expensive. An ionizer, with the property of absorbing SiO_2 , was produced during the war by Dr. Lautz at I. G. Farbenindustrie, the mass being regenerated with caustic soda. Results have been promising but time does not yet permit a definite opinion. Lack of raw material prevents its manufacture at present. Dr. Splittgerber recommends evaporation as the surest method of silicic acid reduction.

Reduction of Carbonic Acid in Feedwater

Carbonic acid may be neutralized in feedwater by the addition of caustic soda but not soda ash, for with the latter the bicarbonate formed is decomposed to generate aggressive carbonic acid. Nor can dosage with caustic soda be regarded as fully satisfactory, owing to free carbonic acid being delivered to the steam as result of splitting of soda in the boiler. It is preferable to remove carbonic acid by heating the water to 212 F and keeping it in open tanks for two hours. The thermic separation of the carbonic acid from the water may be speeded up by adjusting the pH to around 5.5 or 6.0. This can be done by separate acid dosing of the water or by partly desalting it, all the water being passed through an ordinary softening filter first and through a hydrogen filter, then only in such amount that mineral acids formed in the hydrogen filter are capable of completely driving out the water's content of bound carbonic acid. In subsequent thermic separation (deaeration) the equipment must be resistant to water of 5.5 to 6.0 pH, in other words, acid-resistant. A demand for feedwater absolutely without free or bound carbonic acid is obvious with pressures of 100 atm and upward.

Reduction of Oxygen Content

With conventional thermic deaeration a residual oxygen content of 0.02 mg per liter, or less, is usually attained. Further to reduce the oxygen to less than 0.001 mg per liter, which is necessary with Benson boilers, has heretofore required that the feedwater be dosed with sulfite of soda or sulfur dioxide. This is not now recommended, as sodium sulfite at around 525 F and above decomposes to give off sodium sulfide which, in turn, through hydrolysis gives rise to hydrogen sulfide, the injurious effects of which are referred to later. An ex-

cellent method was discovered in Germany in the employment of hydrazin, N_2H_4 . Even minute quantities of residual oxygen react completely to hydrazin, forming water and the inert gas nitrogen:



As hydrazin was employed as propellant for V rockets during the latter war years, its manufacture was controlled. The British allow some manufacture, under control, for certain sensitive boilers, such as the Benson.

Anti-Corrosion in Benson Boilers

Dr. Splittgerber states there are about one hundred Benson boilers in Germany. Of late special corrosion troubles have arisen with these boilers, generally called "Benson sickness." This, however, can be cured by giving the feedwater minute quantities of oil. In Sweden, also, it has been observed that with feedwater containing small quantities of oil, corrosion did not occur in the boiler material, though such might have been expected owing to the relatively acid character of the water.

Caustic Brittleness

Opinion has been general that breakages arising from caustic brittleness were due to intercrystalline cracks. Splittgerber has found, however, that the breakages may proceed both intercrystalline and transcrystalline.

Hydrogen Sulfide Corrosion in Nickel Alloys

In Germany it was found that sodium sulfite in the presence of alkali is converted at around 525 F, and above, to sodium sulfide and sodium tetrathionate. The sodium sulfide is hydrolyzed into hydrogen sulfide which, like the soda-separated carbonic acid, leaves the boiler in the steam. It has also been demonstrated that sodium sulfate in an acid water is reduced to sodium sulfide by the hydrogen formed from the reaction of the water and the iron. A secondary process is reduction of the sodium sulfate to sodium sulfide, giving rise to hydrogen sulfide in the leaving steam. Even at pressures as low as 225 psi, hydrogen sulfide has been found in the steam, as a result of superheated steam being cooled by injection of feedwater dosed with sodium sulfite. In turbines having nickel alloy parts, it has been found that hydrogen sulfide will attack the nickel, forming nickel sulfide, and the resulting corrosion has caused damage.

Anti-Corrosion in Condensate Systems

In Germany, as in Sweden, ammonia has been used as an anti-corrosive agent for acid condensates. Where the steam contains ammonia and air is drawn into the condenser, corrosion of brass tubes is likely to occur owing to the ammonia and air attacking the copper. Splittgerber states, however, that with ammonia below 10 mg per kg, risk of corrosion is seldom present even if the feedwater is not deaerated.

Chlorination of Cooling Water

Chlorination of condenser cooling water is now widely used in Germany. This is partly to destroy micro-organisms which form deposits on condensers and partly to prevent deposits of molluscs in the large cooling water intakes when the water comes from the Baltic or the North Sea. There the chlorine is usually added direct in the form of gas to the pipe lines. In the Klorator System, invented by Professor Ornstein, a saturated chlorine solution is delivered continuously or intermittently to the water supply system and this is found to be quicker in action than direct chlorine gas delivery.

High-Pressure Boiler Feedwater

According to Dr. Splittgerber, a 100-atm boiler should be run on feedwater with the following analysis:

Phenolphthalein alkalinity . . . 37 to 62 ppm CaCO_3
Phosphate concentration 20 ppm P_2O_5
Salts content (solids) under 2000 ppm

Methods of Analysis

An accuracy of 0.02 deg dH, i.e., 0.025 deg eH (Clark degree)¹, is sought in determining the hardness remaining in softened water. Splittgerber employs palmitate solution diluted with undenatured ethyl alcohol, and states certain conditions for temperature, agitation time, test quantities, etc. References to the method indicate that the quantity of soap solution used may be converted to a hardness figure. This basis has been found generally to give quite erroneous results, as a soap solution of a fixed prescription prepared by a qualified chemist is not of general application. IVA² has found that each solution requires checking against calcium chloride solutions of known composition.

Splittgerber agrees with this, but claims his method is more accurate because his solution is more diluted. Nevertheless, the IVA method was claimed to be more satisfactory for checking softening filters, as much smaller quantities of solution are required for each analysis. With very weak solutions such as Splittgerber's, soap consumption is low for very low remaining hardness, but it is as high as 50 ml solution for hardness around 0.10 to 0.15 dH, the highest tolerated before salting a softening filter. This means for the low soap solution the use of a burette of about 50 ml, whereas with the stronger IVA solution a 10-ml pipette is sufficient. A burette with solution is usually left standing from one analysis to another and in boiler houses and laboratories where the temperature may be as high as 20 to 30 C (68 to 86 F) the alcohol in the solution will evaporate fairly quickly, thus making the solution too strong. At the next analysis too small a soap consumption may be recorded, therefore, which may lead to repeated overloading of softening filters and wrong estimate of the feedwater's properties.

The Splittgerber-Mohr method for phosphate concentration determination works with ammonium molybdate solution and control disks of standard colors, whereas the IVA method works with a phosphate reagent consisting of quinine sulfate and a molybdate, giving a grade of turbidity for phosphate standard proportional to the phosphate content.

¹ Nineteen grains CaCO_3 per Imperial gallon, equivalent to approximately 14.3 ppm.

² Ingeniörs Vetenskaps Akademien (Stockholm Engineering Society).

Facts and Figures

Stainless steel tank heads up to 102 in. diameter are now being spun mechanically on a production basis.

Sweating is often more effective than mechanical means in removing hard scale from superheater tubes.

Over six million kilowatts of new electric generating capacity in the United States is scheduled for shipment during the current year.

Mechanically loaded coal mined in the United States increased from 47 million tons in 1935 to 286 million tons in 1948.

Volcanic steam for power generation on a small scale has long been used at Lardarello, Italy; but a postwar project calls for construction there of two new plants of 250,000 kw combined rating.

A new cast-steel alloy containing 19.5 per cent chromium and 9 per cent nickel, with other constituents and identified as "Lebanon Grade 22," is said to be capable of service at temperatures as low as minus 423 F.

According to a report from Mellon Institute, progress is being made in research to convert coal-tar pitch into a satisfactory open-hearth fuel as a possible replacement for petroleum.

The British Electricity Authority reports the average net thermal efficiency of electric generating stations under its control, for the year ended March 31, 1949, as 21.07 per cent.

A peculiarity of titanium is that, although highly resistant to corrosion at room temperature, it is very reactive at high temperatures.

Other conditions being equal, insulation specified for outdoor equipment should be $\frac{1}{2}$ in. thicker than for indoor application to compensate for wind velocities and inclement weather.

Maintenance of a proper alkalinity balance is an important part of any system of boiler control. Too low or too high alkalinity may result in operating difficulties.

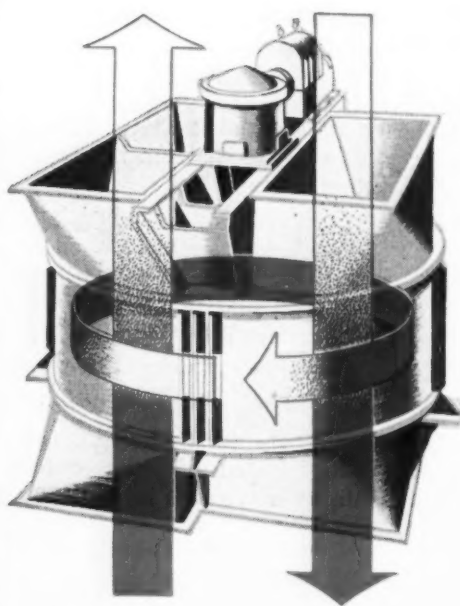
A new estimate of the world's oil reserves, issued by the Petroleum Information Bureau, London, places the present crude oil in the ground as 78,322 million barrels for the world and 23,280 million barrels for the United States. In other words, the United States would appear to possess about 30 per cent of the total.

Fact File on Preheat

No. 2

In the Ljungstrom Air Preheater, air and flue gases are each uniformly distributed as they flow through the heating surface. This uniform flow through the rotating heating element maintains nearly constant temperatures at any given cross-section. "Cold spots," which often initiate plugging, do not exist at any part of the heat exchange surface.

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Economic Factors Involved In Selection of Industrial Boilers

By W. S. PATTERSON* and R. L. RIKER†

Excerpts from a paper before the American Institute of Chemical Engineers at Tulsa, Okla., May 9-12, 1949; also submitted to the First Pan-American Engineering Congress at Rio de Janeiro, Brazil, July 15-24, 1949. Included are various factors governing the number and size of units, steam conditions, and heat recovery equipment. Relative costs are also discussed.

INDUSTRIAL concerns have sometimes led the public utilities in the use of higher steam pressure and temperature. For example, in this country the Philip Carey Mfg. Co. was the first (1929) to install large commercial boilers designed for over 1800 psi; Diamond Alkali Company the first (1939) to use over 2000 psi; and Ford Motor Co. the first (1934) to employ commercially over 900 F steam temperature, in addition to being one of the first (1934) to install a boiler capable of evaporating over 1,000,000 lb. of steam per hour. Other industries have purchased boilers for the same pressure and steam conditions as currently used by the public utilities.

The General Economic Problem

Aside from cost of fuel-burning and fuel-preparation equipment variable factors which influence capital cost of a boiler plant per unit of capacity are: size of unit,

operating pressure, steam temperature, heat-recovery equipment, auxiliary equipment and, of course, quality of product. The kind of fuel is generally fixed by plant location, and if coal is the fuel, the method of firing may be dictated by the nature of coal or size of unit. Increase in capital investment due to high pressure, high steam temperature, high overall efficiency and conservative design will result in lower annual operating costs for fuel and maintenance. The selection problem therefore resolves into adding the annual fixed charges on investment to annual operating costs for various equipment selections to determine which results in the lowest or optimum total annual cost.

Fig. 1 shows the general relation between the components which combine to make up total annual cost. The magnitude of the fixed charge rate is controlled by interest rate and assumed life span for the plant. As the fixed charge rate decreases, the optimum point will move in the direction of higher capital investment if operating costs are constant. In most instances involving boiler plants, the cost of fuel controls the magnitude of operating costs, and as cost of fuel increases, the optimum point will move in the direction of higher capital investment, if the fixed charge rate is constant. It will be noted that the optimum point does not necessarily coincide with the intersection of the component curves.

One of the first determinations that must be made in designing a plant is the number and size of boilers. One large boiler will involve lower investment than two or three small boilers, other factors remaining equal, but minimum investment is not the controlling factor. Selection of number of boilers and total installed capacity in relation to peak load demand may be an involved procedure since it depends on known or assumed variables including the following: peak demand, load factor,

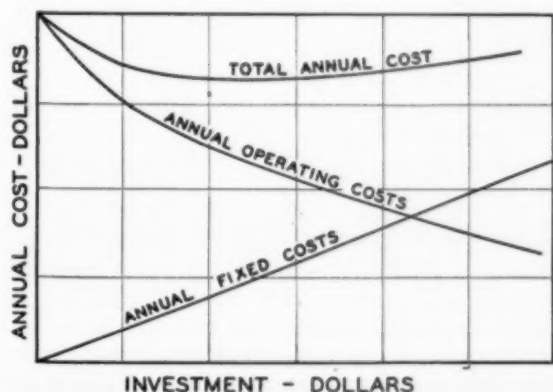


Fig. 1—Relationship of annual fixed costs and operating costs to total annual cost

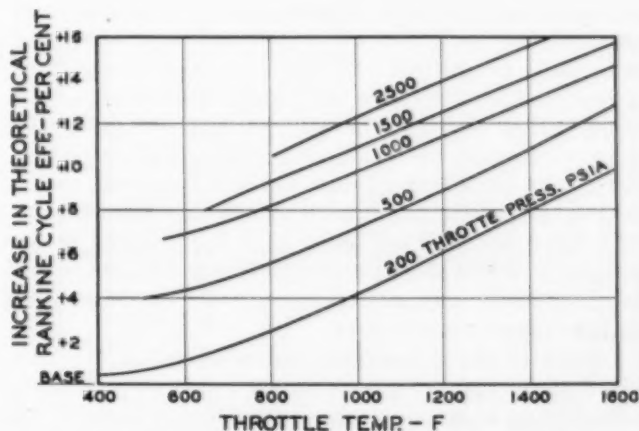


Fig. 2—Rankine cycle station efficiency for condensing cycle as affected by initial throttle pressure and temperature

* Executive Assistant, Engineering Dept., Combustion Engineering-Superheater, Inc.

† Manager, Proposition Dept., Combustion Engineering-Superheater, Inc.

equipment availability factor, conservatism in equipment design, expected increase in peak demand, plant location and degree of isolation, power tie-ins with other plants, nature of industry or process, etc.

Another important step is determination of economic steam pressure and temperature. The effect of pressure and temperature on theoretical Rankine cycle efficiency for a condensing system is illustrated in Fig. 2. The tremendous increases in power station efficiency during the last 25 years have been due largely to use of higher steam pressures and temperatures at the turbine and higher fuel burning and heat recovery efficiency from the steam generating unit. But steam temperature and pressure are not independent variables. Long before alloy materials were available to permit high steam temperature in superheaters and turbines, it was possible to build such equipment to take advantage of the inherent gains due to high pressure. However, increase in pressure without an incremental increase in temperature will result in excessive moisture in the low-pressure end of the turbine. Therefore, during the 1920's when higher pressures were projected, a number of plants resorted to interstage reheat of the steam because steam temperature was limited by materials to about 800 F. Today, thanks to progress in metallurgy, high-pressure and high-temperature steam can both be used, and some recent installations will employ 1050 F steam at 2000 psi at the turbine.

As the design pressure of a boiler is increased the temperature of the coolant boiler water also increases, so that more boiler surface is required for the same efficiency. However, it is sometimes more economical to resort to an economizer for the additional surface and thus take advantage of the lower temperature of the incoming feed-water to produce a higher temperature difference for more effective heat transfer, and a higher efficiency than could possibly be obtained with boiler surface alone. The cost of boiler and economizer surface increases with increased operating pressure, therefore making it more economical on some moderate pressure boiler types to use an air preheater instead of an economizer. There are limitations to both, and for maximum efficiency both are needed and can be economically justified when fuel cost is high.

When an industrial plant requires a large amount of process steam, or process steam and power, it will generally prove profitable to install a boiler plant. In the former case there is no need for high steam temperature and pressure, but in the latter case a moderately high pressure can be justified if steam and power demands coincide in magnitude and time. In such a case steam is generated at a pressure and temperature considerably higher than required for process and is first passed through a prime mover and then exhausted to process. Energy in the exhaust is chargeable to the process and that developed by the prime mover is therefore obtained at a heat rate which is lower than best central station practice. When the two types of load do not coincide in a desirable manner, an extraction type condensing turbine may be the answer.

Choice of steam pressure and temperature for combined power and process steam plants can only be determined by an economic study. From such a study for the paper industry, Robert Krause (1)¹ indicates that the

proper conditions will probably lie between 450 psi, 750 F and 600 psi, 825 F; whereas L. W. Roush (2) in discussing chemical plants suggests 900 psi, 800 F for new plants. For a petroleum refinery, J. B. Glasby (3) discusses an economic study which resulted in a plant extension, using steam at 650 psi, 750 F from a boiler having 86 per cent efficiency, and showing 23 per cent return on the investment. Another chemical manufacturing plant extension now nearing completion, and described by Neil J. Braski (4) will employ 1475 psi and 900 F, while the same company recently dedicated another plant using steam at 850 psi, 900 F (5). The high-pressure boilers (4) will have 100 per cent makeup, as is the case in an oil refinery power plant extension described by Monro and Milbrook (6) where 1500 psi, 900 F were also selected for use with back-pressure turbines. Two recent paper mill power plant extensions (7, 8) have gone to 600 psi, 700 F and 560 psi, 750 F steam conditions, respectively.

Boiler Types, Styles and Sizes

The boiler manufacturing business, large as it is, is conducted to some extent on about the same basis as custom tailoring or dressmaking, so it is very difficult to generalize on types, styles and sizes. There are few truly standard boilers although there may be several standard types. The following generalities are approximately factual for the boiler manufacturing industry.

1. Completely standard boilers requiring negligible engineering time are available from all manufacturers in small sizes only, and low pressure (100-250 psi) and low superheat (50-100 F).
2. Standardized types, with some parts completely standardized to reduce greatly engineering cost and time, are available from some manufacturers in sizes up to 200,000 to 300,000 lb per hour, pressures of 150 to 1000 psi and 650-900 F temperature.
3. Some manufacturers have standard types for the larger boilers (300,000 to 1,000,000 lb per hr) for pressures of 900 to 2000 psi and steam temperatures of 800 to 1050 F, but these are generally "tailor made" as to details.
4. Most small boilers purchased are for low pressure, 400 psi or under.
5. Most large boilers (over 100,000 lb per hr) are built for pressure over 400 psi, and for superheated steam.
6. Oil and gas firing are used on all sizes from the smallest to the largest.
7. Pulverized-fuel firing is not used on very small boilers.
8. Stoker firing is not used on very large boilers.

The authors' company is called upon to design and manufacture steam generating units and fuel-burning equipment in sizes from 3000 to over 1,000,000 lb per hr steam generating capacity, for pressures of 50 to 3000 psi and steam temperatures of 300 to 1400 F with fuel ranging from common coal, oil and gas to acid sludge, tar, coke, waste wood, bark, bagasse, sewage sludge, and even corn, rice hulls and coffee, etc. It has, there-

¹ See Bibliography at end of paper.

fore (to use the custom tailoring analogy), long been the custom to treat each client as an individual to be fitted, shaped and draped to suit his stature, size, style and personal whims and fancies.

But it has become increasingly apparent of late that the cost of such a practice can become an overwhelming burden on the manufacturer, and standardization is necessary to effect cost savings for at least a portion of the size and pressure range that would apply to a small power or process steam plant.

Our smallest truly standard steam generator is a compact oil-fired, forced-circulation unit originally designed to supply steam for car heating on diesel-propelled trains

but adaptations of this design are now available for industrial plants requiring small quantities of steam. This unit has automatic push-button start and stop control and can generate up to 3600 lb per hr at 300 psi from a cold start in a few minutes.

Fire-tube boilers of various styles are well known as to their size, pressure and temperature limitations (approximately 20,000 lb per hr, 200 psi, 150 F superheat) and will only be mentioned in passing. They are highly standardized by most manufacturers.

For small process and heating plants which do not require boilers of more than about 50,000 lb per hr capacity or more than 250 psi, several standardized styles of

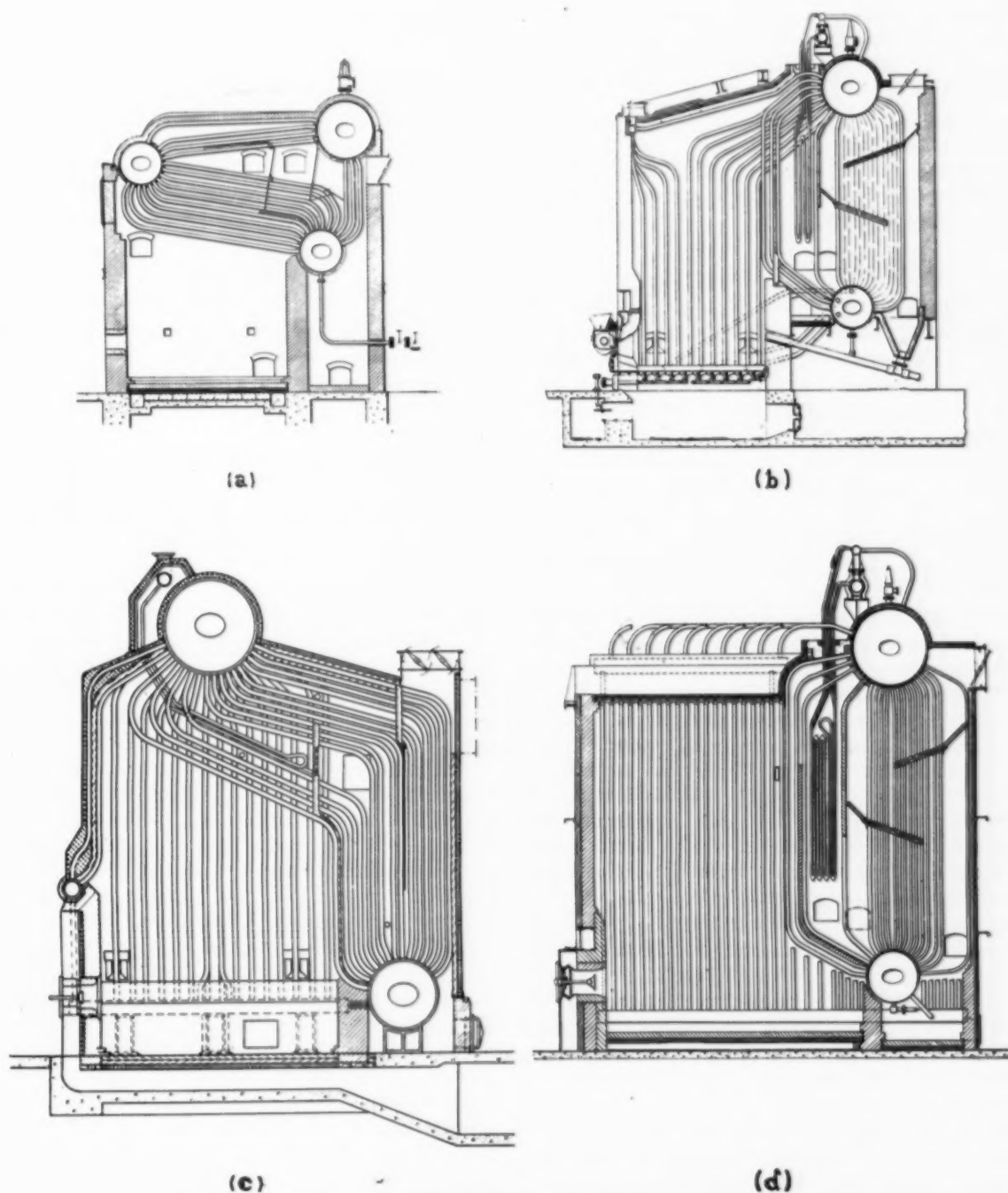


Fig. 3—Four styles of small boilers of standardized water-tube type

(a) Three-drum brick-set unit with refractory furnace; (b) two-drum brick-set unit with partially water-cooled furnace; (c) two-drum "package boiler," steel cased, water-cooled furnace; (d) two-drum steel-cased unit, water-cooled except front wall.

water-tube type are available from most manufacturers. Typical examples are illustrated by Fig. 3 in which Design (a) illustrates a 3-drum low-head brick-set unit; Design (b) is a 2-drum brick-set unit with moderate water cooling of the furnace; Design (c) a 2-drum steel-cased unit with fully water-cooled furnace; and Design (d) another 2-drum steel-cased water-cooled furnace style.

Another 2-drum design is shown in Fig. 4. This boiler, as offered by the authors' company, is a standardized type with some parts and engineering details completely standardized and is available in sizes from 50,000 to 300,000 lb per hr, with pressures up to about 1000 psi and steam temperature up to about 900 F. It has a fully water-cooled furnace and the floor construction and furnace shape are varied to suit the fuel and method of firing. This popular two-drum water-cooled unit may be conveniently provided with a hopper bottom for pulverized fuel firing as illustrated in Fig. 5. This unit of 250,000-lb per hr capacity at 630 psi, 700 F was installed recently in an industrial plant and can burn either pulverized coal or oil. For heat recovery equipment an economizer is seldom used with this type boiler since 87 per cent overall efficiency can readily be obtained with air heater only.

Fuels and Firing Methods

For some localities in the United States the selection of firing equipment is no problem from the standpoint of selecting the primary fuel, and little or no consideration is given to providing for a supplementary or emergency fuel. However, many plants are located in areas where two or more fuels are sometimes available on a competitive price level and under such conditions all large fuel users naturally want to be able to burn the cheaper fuel. The effects of strikes, the business cycle, and probable future availability and price of basic fuels may influence others to make special provisions for emergencies.

Oil and gas are the ideal basic fuels from the standpoint of cleanliness, simplicity of firing equipment and control, operating labor, and boiler availability. They can be burned at higher combustion rates in smaller furnaces than coal and thus reduce the initial plant investment by effecting savings in cost of boilers, and equipment for fuel and ash handling. The two fuels may be burned separately or simultaneously in the same burners, if provided with proper fuel nozzles for dual firing, and there will not be a marked difference in performance except for reduction in efficiency with natural gas and superheated steam temperature with oil.

Coal reserves far surpass known reserves of gas or oil, and coal must therefore be considered the basic fuel of the major industrial areas of the United States. However, it varies widely in composition and each of its constituents has some influence on boiler unit design. In addition, the burning characteristics and ash-fusion temperature must be considered in the selection of equipment.

A chart for comparing coal, oil and natural gas to determine equivalent fuel price, and fuel cost per heat unit in steam produced, is shown on Fig. 6. Cost of equipment and labor for handling, storage, heating, metering, weighing, feeding, pulverizing, and maintenance of equipment for the above operations should

be taken into consideration in arriving at the most economical fuel and firing method. Cost of labor and power to handle, to pulverize coal and for maintenance on feeders, mills and exhausters will vary with the size of plant and type of coal but should fall within the limits of 15 to 30 cents per ton. Any economic fuel comparison must also take into account differences in overall efficiency and power used by auxiliaries.

When considerable heat-recovery equipment is employed the effect on efficiency resulting from differences in final gas temperature is less than that due to differences in moisture content of the flue gas. For coal, oil and natural gas the moisture in flue gas will be roughly 0.5, 1.0 and 2.0 lb, respectively, per pound of fuel burned. At 400 F these figures represent heat balance losses of 4.5, 6.5 and 10.8 per cent respectively. To offset the higher moisture loss with gas or oil firing there will

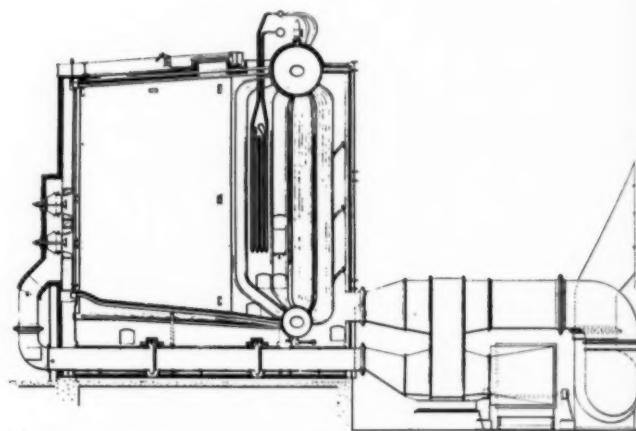


Fig. 4—Typical arrangement of C-E standardized-type two-drum boiler, with completely water-cooled furnace and regenerative (Ljungstrom) air heater, for capacity up to 300,000 lb per hr; pressure up to 1000 psi and steam temperature to 900 F

be a higher combustible loss with coal firing which will vary from 0.25 per cent for large units to perhaps 1.5 per cent for small units, based on pulverized coal firing; and from 1.0 per cent up for stoker firing depending on the kind of stoker, kind of coal and several other factors. The combustible loss with gas and oil firing is negligible with proper operating conditions and equipment.

The authors' company has built more than twenty thousand stokers in 20 different types and has witnessed the development and, incidentally, the decline of many of these types. The reason for so many types is that a different kind of stoker was needed for (1) different kinds of coal, (2) different burning characteristics, and (3) different size boilers. The present popularity of the spreader type is due to the fact that it can be more universally applied, is simple to operate and less costly to maintain. The fines are burned in suspension and the coarse particles in a thin fuel bed on the grate, which makes spreader firing responsive to load changes. Stokers are not generally used for extremely large boilers because of the difficulties involved in designing and operating grates of over 600 sq ft in area, and the fact that the required stoker width is greater than the required boiler width thus resulting in an expensive boiler. For large units the traveling grate type and the spreader type with continuous ash discharge are predominant.

Pulverized coal is popular in boiler sizes from 50,000 to over 1,000,000 lb per hr steam capacity because of the wide variety of coals that can be burned. However, when the unit is designed for good coal there may be a reduction in capacity or availability, when burning poor coal. This fact must be considered in the economics of selection and weighed against the probability of getting or having to burn, poorer coal than might be normally available. Provision for burning coal that is poor in the sense of low grindability, low heat value, low ash-fusion temperature, high ash content and high moisture content results in increased capital investment due to more or larger pulverizers, larger furnace, wider superheater tube spacing, and lower gas velocity in boiler and economizer.

Pulverized coal is not generally used for firing boilers smaller than 50,000 lb per hr steam capacity because in such sizes pulverized fuel equipment costs more than stokers, has less flexibility for very low loads and requires greater skill of operation. When the base fuel is oil or gas but coal must be considered as a future fuel, stokers would be preferred for small boilers, and all the standard designs shown in Fig. 3 are capable of conversion to stoker firing when set high enough to allow for stoker and ash pit.

Heat Recovery Equipment

The principal reasons for the use of heat-recovery equipment have already been stated. The water tem-

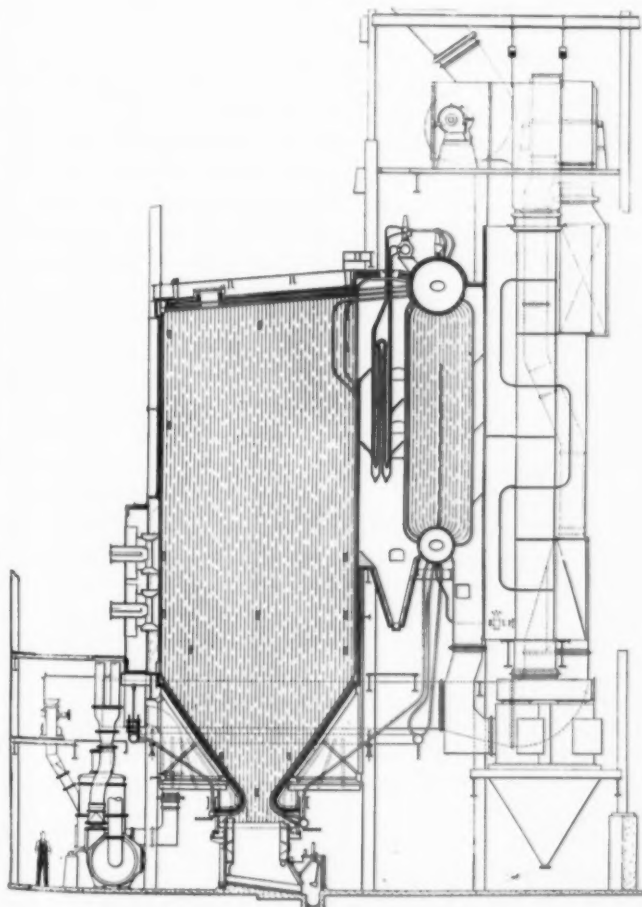


Fig. 5—Pulverized-coal-fired unit of 250,000-lb per hr capacity at 630 psi and 700 F

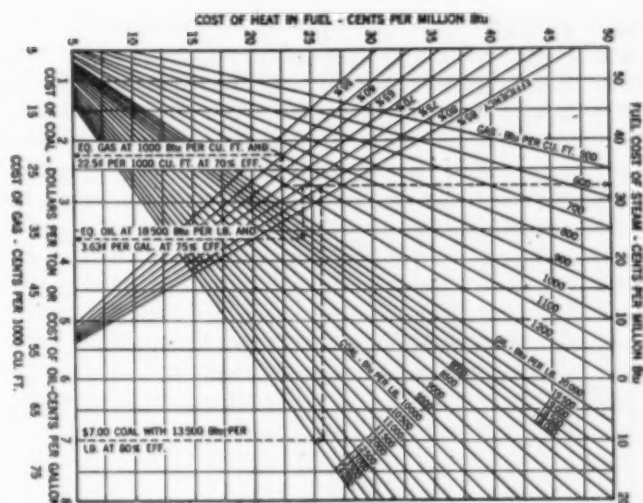


Fig. 6—Chart for comparing coal, oil and gas on equivalent price basis

perature in a boiler increases with operating pressure from 212 F to 705 F as the pressure is increased to 3200 psi. Therefore, since the flue gas cannot economically be cooled down to the temperature of the boiler water, a high efficiency cannot be obtained on a high-pressure boiler without the use of heat-recovery equipment.

An economizer increases the efficiency of a boiler unit because, by using counterflow of feedwater and gas, the incoming feed rather than boiler water temperature becomes the minimum theoretical limit to which the gas can be cooled. However, with the regenerative cycle considerable feedwater heating is done with steam extracted from the turbine and the resultant high feedwater temperature (sometimes over 400 F) limits the economizer heat recovery. Under such conditions the permissible size of the economizer is also sometimes limited by the amount of heat that can be absorbed by the feedwater before reaching the saturation temperature.

It is sometimes impossible to obtain the desired efficiency on a stoker-fired installation with an air heater alone because the resulting air temperature would exceed the limit generally considered permissible for stokers, which is 300–350 F. In such cases a large economizer and no air heater may prove the most economical because, although some air heater surface might appear to be justified; the increased cost of ducts and forced-draft fans may be enough to throw the balance in favor of the more expensive economizer heating surface. On the other hand, when the specified overall efficiency is over 85 per cent it will generally be necessary to use an air heater in addition to the economizer. The most economical combination will then be the largest possible air heater consistent with the air temperature limitation, and only as much economizer surface as required to get the efficiency. The approach to selection of heat-recovery equipment for oil, gas or pulverized coal firing is different, because the air temperature limitation does not exist. In fact, for direct-fired pulverized-coal units an air temperature of 500–600 F is necessary to maintain rated pulverizer capacity with high moisture coal.

The theoretical minimum exit gas temperature obtainable with an air heater is the ambient air tempera-

ture at the forced-draft fan but in practice 275 F to 350 F is the minimum practical limit at maximum load. The actual metal temperature will be lower than the gas temperature and the presence of SO₃ and water vapor in the gases raises the dew point to such an extent that corrosion and plugging may occur, thus increasing maintenance costs and reducing availability, when the exit gas temperature is too low.

But there are other limitations to an air heater. For example, the air-flow rate will be appreciably less than the gas-flow rate so that for each 100 deg F gas-temperature drop there will be 125 deg F air-temperature rise. Under such conditions 400 deg F gas drop means 500 deg F air rise or 600 F preheated air, and such a heater if designed for 300 F leaving gas temperature would have 700 F entering gas temperature. Some high-capacity, high-pressure boilers cannot be eco-

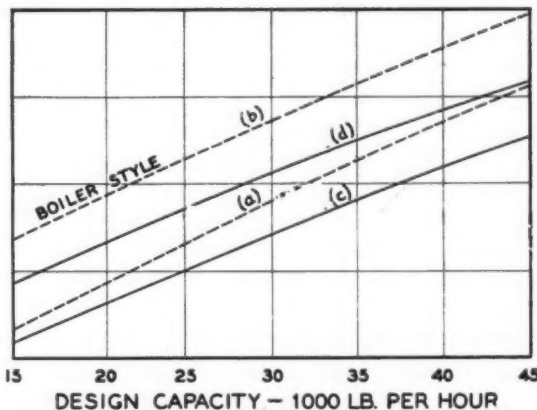


Fig. 7—Relative costs of pressure parts, steel and erected settings plotted against boiler capacity for the four boiler styles shown in Fig. 3

nomically designed to produce such a low gas temperature without an economizer and therefore an economizer and air heater are both needed to produce a final gas temperature of 300 F. In the case cited above it would be uneconomical to design a heater for 500 deg F gas drop because the hot-end temperature difference would be less than 100 deg F, even with counterflow, thus resulting in a very large heater.

Unit Cost Comparisons

Fig. 7 is a relative price comparison of the four boiler styles shown in Fig. 3, including setting materials and setting erection but exclusive of burners, fans, ductwork, etc. However, since these will cost about the same for each of the units, the curves of Fig. 7 may be taken as a real cost comparison.

It becomes apparent that the completely standardized "package boiler," Fig. 3(c), with its low maintenance water-cooled furnace is less expensive than the other types; and even the vertical two-drum steel-cased unit, Fig. 3(d), is less expensive than its brick-set counterpart, Fig. 3(b). After many years of design, manufacturing and operating experience it is our feeling that a premium in initial investment is justified for a modern steel-cased water-cooled furnace setting from the standpoint of maintenance alone, especially when consideration is given to loss of plant capacity during outages for repairs. It is therefore very significant that a water-cooled unit such as the "package boiler" is not only lowest in

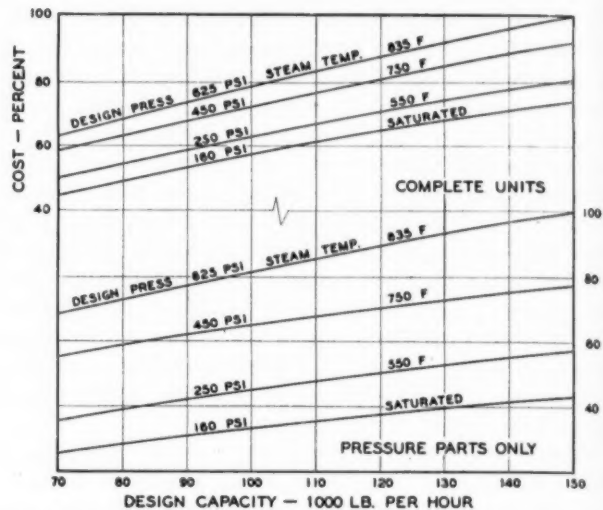


Fig. 8—Chart showing effect of design capacity, pressure and steam temperature on cost of pressure parts and on complete units of the style illustrated in Fig. 4

price but also quickest on delivery, all due to complete and thorough standardization; but it must be accepted "as is" without alterations to realize these savings in cost and time.

Fig. 8 shows the effect of boiler size, design pressure and steam temperature on (1) the cost of pressure parts only, and (2) cost of a complete medium-sized unit of the type shown in Fig. 4. Four combinations of pressure and temperature are used. The lower group of curves shows the cost of pressure parts only, for variable size and operating conditions, plotted as a percentage of the cost of pressure parts for a 150,000-lb per hr unit designed for 625 psi with 835-F steam. It will be noted that there is considerable spread between the curves because increased pressure means thicker tubes and headers for furnace walls, boiler and superheater as well as thicker drums and more expensive fittings; and higher steam temperature means a larger and more expensive superheater.

The upper curves show the cost of the total unit including burners, air heater, fans, ducts, etc., for the same units in the same size range and all selected for the same

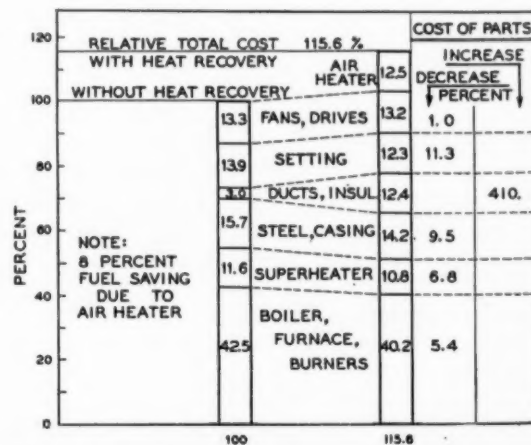


Fig. 9—Chart showing effect of air heater cost on relative total cost and cost of other parts for unit similar to Fig. 4

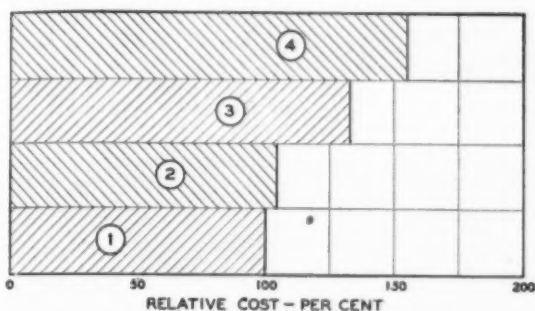


Fig. 10—Charts showing relative boiler unit cost in planning future or present use of pulverized coal firing

(1) Gas or oil firing, no provision for pulverized coal; (2) boiler unit raised on stilts to permit enlarging furnace; (3) boiler and furnace installed for pulverized coal, less pulverizers, feeders, soot blowers, etc.; (4) same as (3) but including, pulverizers, feeders, etc., complete.

overall efficiency. The cost for each size and operating condition is again plotted as a percentage of the cost of a 150,000-lb per hr unit designed for 625 psi with 835 F steam temperature. It will now be noted that the spread between the curves is much less, as would be expected, indicating that in terms of overall cost of a complete unit the incremental cost increase for higher pressure and temperature is not very great. The curves also show that a single 150,000-lb per hr unit would cost 20 to 25 per cent less than two 75,000-lb per hr units designed for the same pressure and temperature conditions, but without any credit for saving in engineering which would apply to a two-unit contract. For this type of boiler this engineering credit would be only about 5 per cent.

An interesting cost analysis showing the effect on overall cost, and cost of individual parts, due to the addition of an air preheater is shown in Fig. 9. The boiler unit selected for this study was of 200,000 lb per hr capacity and of the style shown in Fig. 4. An air heater capable of decreasing the fuel consumption by 8 per cent was selected, resulting in lower gas and air weights, all of which make it possible to use a smaller boiler unit with resultant savings in some parts to compensate at least in part for the two items which greatly increase the cost, such as ducts and air heater. Even the forced- and induced-draft fans, although operating at higher pressure due to the air heater, may be selected for less volume, with the net result of practically no change in cost. The chart shows the percentage of the total cost due to various items for each case, and their increase or decrease in cost for the unit with air heater compared to the unit without heat-recovery equipment. The net cost increase is only 15.6 per cent for a fuel saving of 8.0 per cent.

It has been previously mentioned that air heaters are limited in the amount of heat recovery by the approach of the air leaving temperature to the gas entering temperature, or the hot-end temperature difference. When the hot-end temperature difference is 100 deg F or less, the increase in air-heater cost for a given increment in heat recovery or efficiency becomes exorbitant. Nevertheless, on large boiler units which may operate at a high load factor over a long number of years with high-priced fuel, the necessary heat recovery equipment to reduce the gas temperature below 300 F can often be economically justified.

The necessity of planning for future pulverized fuel in some localities normally using gas or oil has previously been discussed. In other plants "dump" gas is available at a very low price compared to the price of a sure supply, and economic studies have indicated that such plants can justify complete pulverized fuel equipment as part of the initial investment. Fig. 10 shows the effect on capital cost of boiler equipment for the following alternative solutions: (1) Simple gas or oil fired arrangement with no provision for coal firing; (2) boiler unit set on stilts to permit rebuilding furnace to accommodate pulverized fuel; (3) initial installation of proper furnace for pulverized fuel but omitting coal feeding, pulverizing and burning equipment; and (4) complete boiler unit designed for multiple fuel firing including pulverizers, fuel piping, burners, soot blowers, etc.

Industrial Waste-Heat Boilers

No industry can afford to overlook the possibility of generating a considerable portion of its steam requirements through the use of waste-heat boilers, particularly if the price of fuel is high. Many industries integrate waste-heat boilers into their overall plant cycle as a reliable and large source of steam for process or power.

A typical example is the pulp and paper industry where modern chemical recovery units are used for this purpose. Fig. 11 illustrates a typical unit, and shows the parts necessary for evaporating and burning the

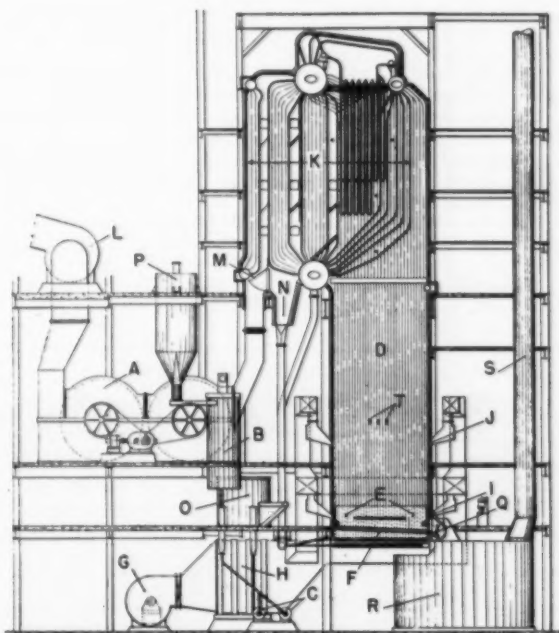


Fig. 11—C-E waste-heat and chemical recovery unit for pulp mill

A—cascade evaporator; B—salt-cake mixing tank; C—heavy black liquor pumps; D—furnace; E—lighting-up oil burners; F—smelter hearth; G—forced-draft fan; H—steam air preheater; I—primary air ports; J—secondary air ports; K—superheater-boiler-economizer; L—induced-draft fan; M—economizer bypass damper; N—boiler ash hopper; O—ash dissolving tank; P—salt cake make-up silo; Q—smelt spout; R—smelt dissolving tank; S—smelt tank vent; T—black-liquor burners.

waste liquor; for reducing, smelting and dissolving the recovered chemicals; and for generating and superheating steam at whatever pressure and temperature is required to satisfy the plant requirements. Units of this type have been built for as high as 150,000 lb per hr continuous steam output, and for design pressure and temperature up to 950 psi, 750 F.

Roughly speaking, a gas temperature of 1000 F will justify a moderate pressure waste-heat boiler, but low-pressure boilers have been used on diesel engine exhaust at 500 to 700 F and have been proposed for operation on gas-turbine exhaust.

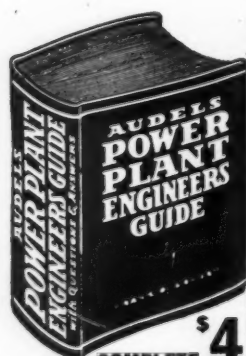
Waste-heat boilers have been quite extensively used also in the cement, steel and chemical industries.

Conclusions

It will be obvious that many interrelated economic and engineering factors are involved in the proper selection of steam generating units for any plant having moderate or large steam and/or power requirements. Specialized advice, and studies based on the particular plant problems are a necessary prerequisite to the preparation of the steam plant specifications. When the plant or company has a competent engineering staff thoroughly familiar with the economic and engineering problems involved, a satisfactory boiler selection can generally be worked out with the help of the boiler manufacturer's engineering and sales forces. In all other cases it would seem wise to employ a competent consulting firm to prepare the steam and power plant specifications for the purchase of new equipment.

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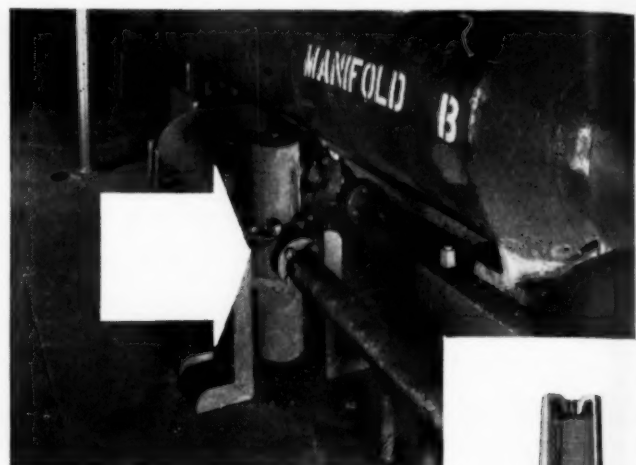
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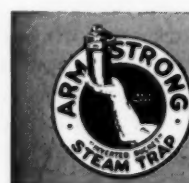


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FLASH DRYING OF BARK*

By W. G. TAMBLYN

Assistant Plant Engineer,
Great Lakes Paper Company

FROM 1928 to 1939 all bark from the wood room was piled and stored on mill property, with the result that by 1939 there was approximately 100,000 tons in the pile. Space available in the vicinity of the wood room was limited and adjacent property was considered too valuable for refuse storage. It was imperative, therefore, that some other means of eliminating refuse be found.

A study of many bark-burning furnaces and bark presses was made. Bark in the piles and coming from the drums contained approximately 80 per cent moisture and, without use of an auxiliary fuel, it would have been necessary to reduce moisture to approximately 65 per cent. Of the different types of presses studied, the Nekoosa press was considered most suitable and four of these, driven by a single 75-hp motor, were installed in 1939. They handle bark from 1000 to 1500 cords per day during peak periods. Yearly wood consumption at this time was between 150,000 and 200,000 cords and the wood room was operating on a 12-month basis. Approximately 60 per cent of the wood was water-delivered with only 80 per cent bark coverage and the remaining 40 per cent was rail-delivered with 100 per cent coverage. Based on average bark coverage, the dry weight of bark figured approximately 225 lb per cord of wood or 22,500 tons dry weight per year for a consumption of 200,000 cords.

For such capacities the four presses reduced the moisture content from an average of 78 to 65 per cent, or to a point where it was possible to burn the bark without auxiliary fuel.

Dutch ovens were incorporated in an existing 999-hp Heine boiler which was already equipped with two Strong-Scott pulverizers. Two dutch ovens were erected below the firing floor and in front of the boiler. The existing ash pit was removed so that the secondary combustion chamber in the boiler proper was increased in size by the distance between the firing floor and the basement floor. Two ovens were employed because of the greater brick area for heat reflection compared with a larger single unit. Existing structural steel was also a factor in this decision. Before the initial start-up of the flash drying equipment early this year, the ovens were dismantled, new supporting steel erected and Detrick sectionally supported walls and arch installed. The general dimensions, however, were maintained as well as the drop nose arch and

bridgewall at the back of the ovens or between the ovens and the secondary combustion chamber.

Refuse was fed into the ovens by two discharge spouts through the arch in each section. Aside from air drawn in through these spouts in the roof of the ovens, all air for combustion was blown through the grates at an available pressure of 4 to 5 in.

This paper summarizes various stages of bark disposal at the Great Lakes Paper Company plant at Fort William. The period covered is from 1938 to the present and the method of disposal ranged from stacking the bark on mill property, through to the present system of flash drying and burning. Savings up to 75 tons of coal equivalent per day are being effected, as well as eliminating the problem of bark and refuse disposal.

but this is not developed unless the grates are completely covered. This air is preheated to 300 F.

The combination of presses and dutch ovens was satisfactory and under ideal conditions coal savings of around 50 tons a day were effected. For a nine-month period in 1940, with an average moisture content of 63.4 per cent, the total coal

equivalent of refuse burned was 6086.5 tons, or an average of 676 tons per month. It was also found during the early days of dutch oven operation that a combination of reclaimed and new bark was most satisfactory. Although this was contrary to the generally accepted principles of bark burning, results were obtained that warranted this practice.

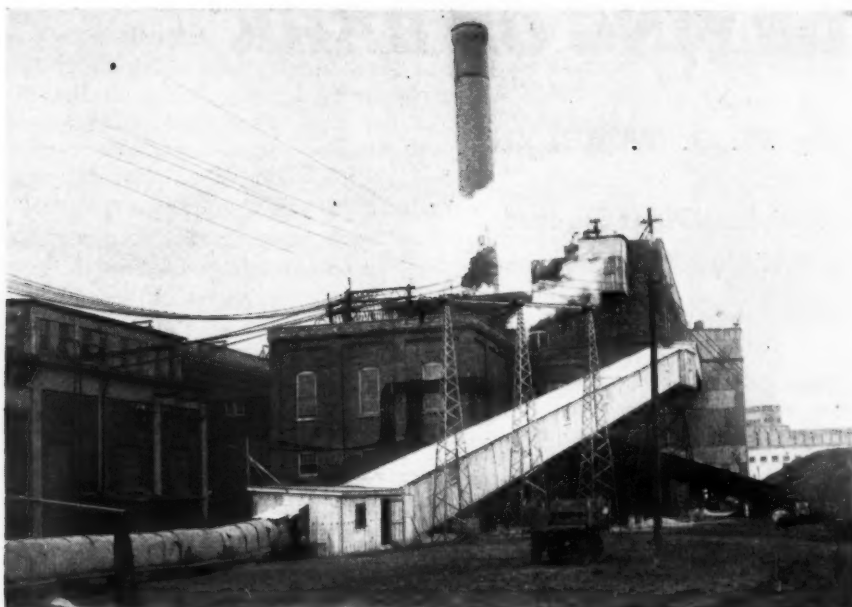
However, there were difficulties with the system on numerous occasions, particularly during the summer barking period. The pulverizers and burners were not disconnected at the time of converting the boiler and adding the dutch ovens, and they were used from time to time during periods of high moisture content in the bark, although the two fuels were never fired simultaneously. The work involved when the fire would go out was both extensive and unpleasant. Nevertheless, for the conditions during its use, the system was successful and economical from the points of both coal savings and refuse disposal. It had proved that steam production was possible with refuse up to 65 per cent moisture without the use of an auxiliary fuel and also provided valuable data and experience for the design of further refinements and improvements, including the flash drying system.

In 1942, with increases in both unbleached sulfite and newsprint production contemplated and planned for, and with the consequent increase in bark quantities, the question of increasing the rate of disposal arose. Further extensions of the



Portion of bark pile at Great Lakes Paper Co. plant

* From a paper presented at the Summer Meeting of the Canadian Pulp and Paper Association, Niagara Falls, Ont. June 3, 1949.



Refuse conveyor to boiler house

existing system, that is, additional dutch ovens on another boiler, or means to increase the rate of burning in the existing unit were both studied. The latter method would have involved some means of reducing the moisture content before the fuel entered the ovens.

Numerous types of bark dryers were reviewed, but it was found that we were already obtaining better results with bark presses and preheated air than any of the mills throughout Canada with dryer installations. It was therefore felt that something new in dryer design was essential to warrant an extensive installation.

Raymond Pulverizer Division of Combustion Engineering Co. had had considerable experience with the flash drying of sewage sludge and with spent grain. Hence, it was decided that a pilot plant should be set up in the Great Lakes boiler house to determine the feasibility and then the most efficient procedure to flash dry wood refuse and bark.

Flash drying has been defined as the practically instantaneous removal of moisture by turbulent mixing of hot gases and wet particles. The system consists essentially of a combined mixing mill and fan plus a cyclone separator. The dryer is actuated with approximately 50 per cent of the hot furnace gases when all of the bark burned is passed through it.

The most important prerequisite to a flash drying system and, incidentally, to efficient combustion with or without drying, is the smallest particle size commensurate with reasonable power requirements. The investigations, therefore, were not only concerned with the drying operation but particularly with reduction of the bark to a fineness where drying would be economical. It was originally considered that a fineness of 80 per cent of the bark through a quarter-inch screen would be required.

The plan was to reduce the bark to a fineness where not only the drying would be economical but also where the dried

bark would burn in suspension in the boiler proper. This would eliminate the dutch ovens and perhaps increase the boiler efficiency. Experiments were conducted on different types of hogs and even on steam disintegrators to achieve this end. It soon became apparent that such reduction of particle size was impossible within reasonable power requirements and it was decided to maintain the existing system of feeding the bark to the dutch ovens rather than burn the material in suspension. A Mitts & Merrill Co. hog gave comparatively good results on relatively small test samples and it was planned to incorporate two of these in the new system.

To achieve the fineness thought necessary for the flash dryer the hogs were to operate under an air-separation system.

That is, the conveying media away from the hog was to be air, and by balancing the air pressure against openings around the discharge side of the hog, it would be possible to remove the fine particles of bark and allow the coarse material to recirculate for recutting. Although this seemed satisfactory on test samples, it proved impracticable in actual operation. The effect of size of fuel particles cannot be overstressed.

Another consideration affecting desired particle size is the difficulties involved in conveying wet bark whether by air or mechanical means. Long stringy pieces tend to wrap around any moving part and eventually to bind the equipment. For this reason the center parts of the fans conveying the material from the hogs were covered with a shield, and flash dryer included special clearing bars between the stationary and rotating cage bars. The latter were to eliminate any building up of bark stringers on the cage bars and they have, in fact, been very satisfactory.

Basis of Performance

Performance of the flash drying equipment was based on feeding 230 tons per day (bone-dry basis) of pressed and hogged bark containing approximately 63 per cent moisture, of which 150 tons per day was to be fed through the flash dryer and the remainder diverted directly to the dutch ovens. It was assumed that gas for the flash dryer would be available at a temperature of 1400 F and 58,000 lb per hr of this gas would be required at that temperature. The equipment was to be capable of drying 150 tons per day from an inlet moisture of 63 per cent to an outlet moisture of 45 per cent.

Bark from the drums is fed directly to the presses by a scraper conveyor. The feed to the presses is arranged so that any excess of bark, that is, amounts greater than the presses will handle, is carried beyond the presses to a pile. From the pile, another scraper returns bark to the scraper ahead of the presses. In this way there is



Discharge of cyclone separator and screw conveyor feeding the dutch oven

always an excess of bark fed to the presses, and the excess is recirculated. In periods of heavy barking the pile is therefore built up and in periods of light barking the pile is cut down.

The hogs, fans, flash-drying equipment, etc., are all in one building which was added to the side of the boiler house, opposite the dutch ovens. The bark enters the building on a 24-in. rubber belt conveyor approximately 50 ft above the firing floor. From this conveyor the pressed bark and other refuse can be diverted to the hogs or, alternately, can bypass all the hogging and drying equipment and be fed directly to the dutch ovens as in the earlier installation. In case of hog failure, therefore, there is no change to either the particle size or moisture content of the pressed bark.

Fans on the hogs were to classify the product and then convey it to a cyclone approximately 70 ft above the firing floor. From the cyclone the hogged bark was fed by belt conveyor to an active bottom bin

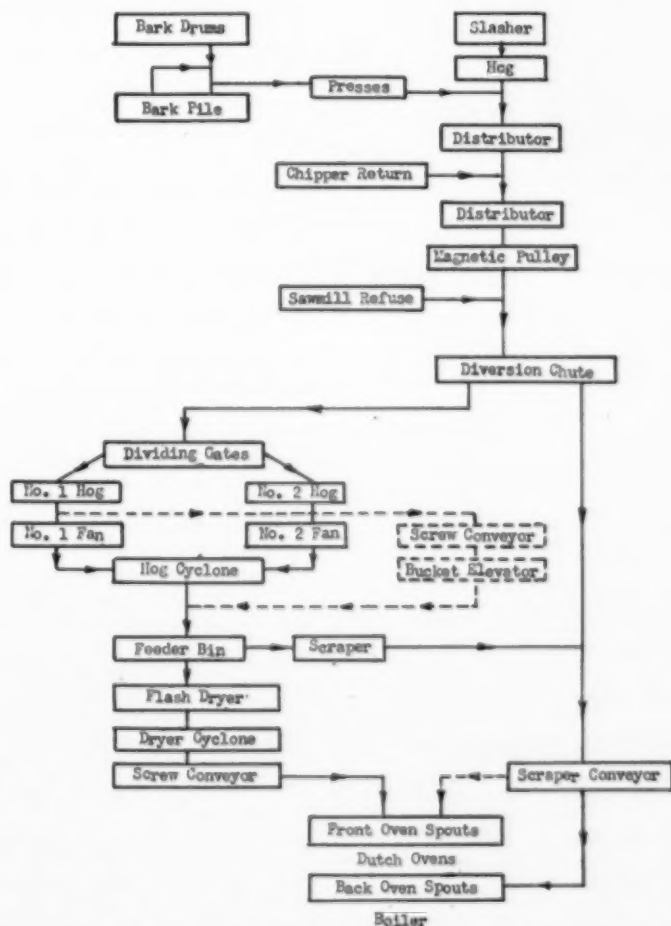
others, which, in turn, feeds the flash dryer.

The feed spouts to the dutch oven are both in the front and the back; the dried bark feeding the front spouts and the bark carried over the active bottom bin feeding the rear spouts. Slide gates also provide for feeding undried hogged bark to the front spouts if necessary. To keep the grates under the rear spouts covered, it is necessary to allow sufficient bark to bypass the drying equipment for this purpose. This is controlled by the variable-speed drive on the bottom discharge of the bin. The amount of bark carried over without drying varies under different conditions but is approximately 40 per cent of the total.

The single screw at one end of the bin carries the hogged bark over the hot gas duct going to the flash dryer and the bark drops into the gas stream about 6 ft from the outer face of the dryer. The hot gases are carried from the top of the front wall of the boiler by a steel duct four and one-

gases and vapor are relieved to atmosphere at the top of the cyclone and the dried bark drops into a screw conveyor which carries it to the two front spouts of the dutch ovens.

Instrumentation for the system is not extensive. The controlling factor is the cyclone vent temperature which is set for



Flow sheet for bark at the Great Lakes Paper Company, Ltd., Fort William, Ontario

which was to regulate the feed to the flash dryer. On top of this bin was a scraper conveyor to carry the excess hogged bark directly to the chutes over the dutch ovens. The bottom of the bin consists of 7 screw conveyors feeding one screw conveyor, the latter at right angles to the

half feet square and lined with a 3-in. refractory. The gas temperatures to the flash dryer are controlled by a butterfly damper and by tempering dampers which are interconnected. Besides mixing the hot gases and hogged bark the flash dryer conveys the bark to a lined cyclone. The

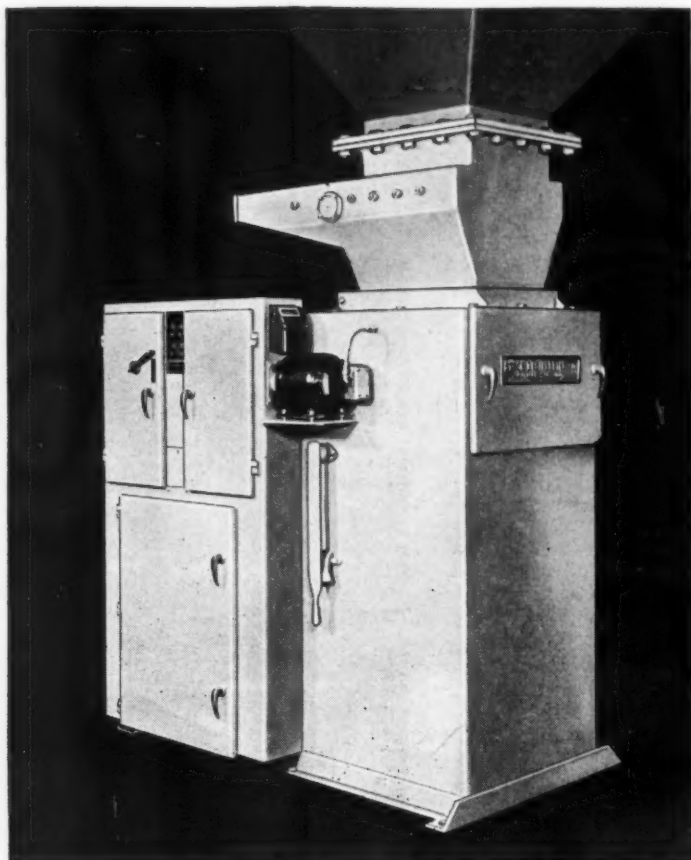


Drive end of flash dryer

400 F. With varying quantities of bark and different moisture contents, the quantity and temperature of hot gas required to maintain this constant vent temperature will change accordingly. The only other temperature recorded is the dryer inlet temperature which may vary in normal operation anywhere from 850 F to 1400 F.

Experiences

The above brief description covers the equipment as originally installed and initially operated. That certain changes would be necessary and the limitations of a pilot plant illustrated, was foreseen. In the initial stages of operation some of the equipment was disappointing while some exceeded expectations. The first difficulty was plugging of the hogs by surges of bark, even with less than average loads. Although driven by a 125-hp motor at a speed of 1200 rpm and with a terrific momentum due to the size and weight of the rotor, the hog would stall in a matter of seconds under moderate loads. This plugging was caused by the air separation system which rejected the heavier material for re-hogging. Although the accepted material that was finally carried off by the fan suction was extremely fine, it was immediately seen that to achieve such fineness for large quantities of pressed bark would require a great many hogs either in series or in parallel. The power requirements to achieve such ends would be too great so that the only alternative for increasing the capacity was to allow a



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coarser product to enter the dryer. This was done by eliminating the baffles at the hog discharge and allowing the fan suction to free the hog of all particles regardless of size. This changed the function of the fans from both a separating and conveying media to merely a conveying medium.

It was only after the separating system was removed from the hog that the flash dryer was tested. With even larger particles than anticipated, the moisture content was reduced from an average of 37 per cent for quantities up to 75 tons per day (bone-dry basis). The rate of feed was limited to this figure of 75 tons by the existing press capacity and by the fact that sufficient bark must bypass the dryer to cover the back grates of the oven. The discharge from the bin was measured and weighed and the bin calibrated for different settings on the Reeves drive. In this way it was possible to calculate the approximate tonnage going through the dryer alone, but the amount bypassing the dryer can only be estimated by visual inspection and rough calculations on steam flow. Based on the calibrated discharge rate of the bin the dryer has operated at or near its design capacity for short intervals without any apparent difficulties, by eliminating excess bark going to the rear of the dutch oven.

Steam Jets Tried

In an attempt to avoid the necessity of bypassing some of the bark around the dryer, steam jets were placed at the bottom of the chutes going into the front of the ovens to force some of the dried bark to the back for grate coverage. This reduced the high excess air and thus raised the furnace temperature to the level required for the proper operation of the flash dryer. During a three-hour period in which this method was tried it is estimated that the dryer was operating at a rate of 104 bone-dry tons per day and the moisture content in the bark before hogging was 60 per cent and after drying only 35.8 per cent. Dryer inlet temperatures were averaging 1160 F and cyclone vent temperature averaged 380 F. Cyclone temperature control was on 385 F and tempering damper closed. The CO₂ leaving the boiler averaged 10.1 per cent.

The relatively lower maximum vent temperature of 400 F from the flash-drying system, compared to the higher stack temperature of approximately 490 F from the original boiler unit under similar fuel and steaming conditions, represents an initial increase in overall thermal efficiency, since this applies to approximately half of the total weight of the products of combustion. Further improvement in efficiency is indicated by the ability to burn the dried fuel with much lower excess air and better control. The higher resulting furnace temperatures also improve the heat absorption rate of the boiler surfaces and the reduced gas flow through the boiler gives a lower boiler exit temperature.

The greatest effect of the flash dryer is in the removal of approximately half of the gases from the furnace and in using these gases for pre-drying outside of the furnace. Thus the boiler, the air heater, the induced-draft fan and the stack are required to handle only half of the gas weights nor-

mally produced to generate the same amount of steam. Furthermore, the moisture removed is vented and does not enter the furnace. The improved burning rates achieved with dried bark plus the reserve created in the heat recovery equipment by the greatly reduced gas flow per pound of steam generated, are expected eventually to double the burning rate and steam production of the original unit.

Other difficulties that arose were associated with the conveying system for the material.

Conclusion

There are, undoubtedly, many improvements that can be made on the present system, but the only reliable method of effecting such improvements is by trial and error. The period of investigation by Great Lakes Paper has now been so prolonged and the present system is giving such satisfactory results that further tests or modifications are unlikely at this plant for some time. Perhaps the most evident improvement would be to flash dry all of the bark rather than only 50 to 60 per cent of it. There are several considerations involved in such a step. In our own case it would involve changes to the dutch ovens. There is not sufficient room between the grates and the arch to feed 100 per cent of the bark through the two front spouts without some means of distributing the pile so formed. This might be accomplished by traveling grates or by air or steam nozzles.

Under the present system, by having a high moisture reduction in the fuel firing the front of the ovens, the rate of combustion and fuel bed temperatures are high in this location. The fuel that has not passed through the dryer must pass through the gases coming from the front of the ovens before hitting the back fuel bed, with the result that there is considerable drying of this fuel in its drop to the grates.

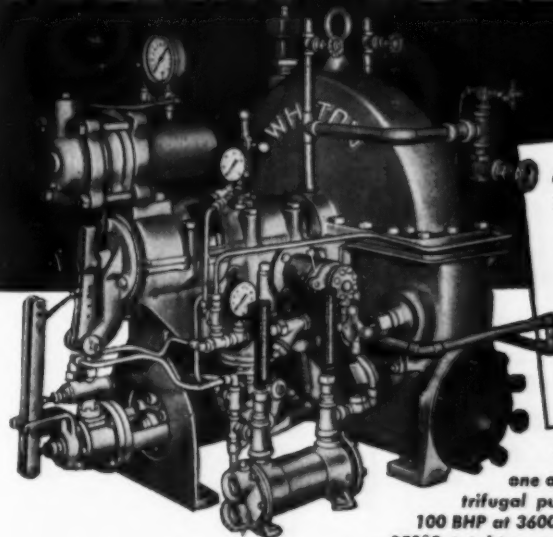
The capacity of the present bark drying and burning system has only been limited by the amount of 63 per cent moisture bark, which has been obtainable from the presses. As has been mentioned previously, it is necessary to feed undried, hogged bark to the rear oven spouts to obtain reasonably complete grate coverage, since the dry bark conveyor does not reach them. This has limited the amount of bark available for predrying and since the flash dryer is normally operating at only partial load, it is discharging a drier product than would be expected at full load. While the design has been based on 150 tons of bone-dry bark per day with an inlet temperature of 1400 F and an outlet temperature of 400 F, a higher feed rate may be possible. This would give a lower exit temperature and remove more total water, but discharge a wetter bark. The limitations in bark rate through the flash dryer will be reached when an increased feed rate of the present sized bark begins to cause plugging trouble in the system because it is not being dried sufficiently.

To summarize, the problem of disposal has been eliminated, the method of disposal has proven satisfactory and economical, and considerable coal savings are being effected.

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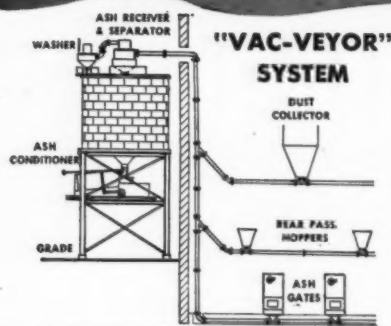
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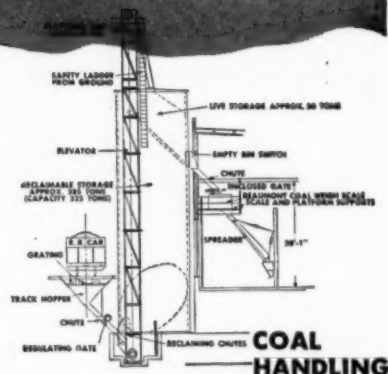
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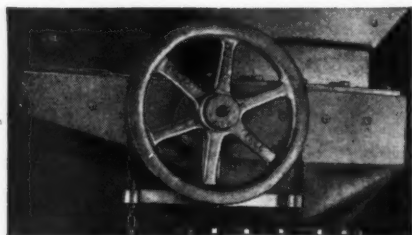
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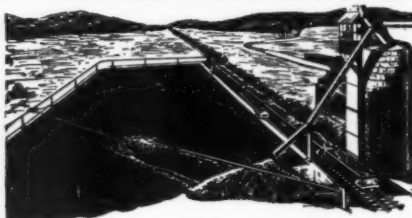
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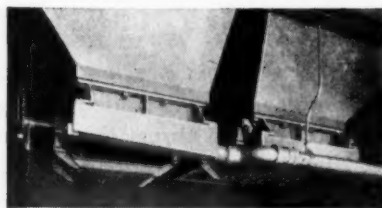
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Position of the British Electricity Supply Industry

The British Electrical Power Convention, held during mid-June, had as one of its features an address by The Rt. Hon. Lord Citrine, chairman of the British Electric Authority. After reviewing the work of the Authority over the preceding twelve months, the speaker turned to the question of adequacy of the British power supply.

Commenting upon the necessity for expensive capital developments, Lord Citrine pointed to conflicting interests at home and in the export field. "More power stations are urgently needed and the British Electric Authority are constantly making the utmost efforts to construct them, but over one-third of the heavy electrical generating machinery, boilers and plant, is being exported. This raises a high question of policy. The ability of the industries of the country to meet ever-growing competition in the export field is inseparably bound up with the provision of adequate supplies of electricity to enable more efficient production to be achieved. There is a close relationship between the cost of the product and the power resources available per employee. The claims on manufacturing capacity in this country (Great Britain) as between plant for power stations and goods for export, are therefore complementary rather than competitive, and an improvement in the supply of electricity will be reflected in the exports to the ultimate overall advantage of the country. Despite recognition of the palpable need for maintaining exports, concern has been expressed many times at the exceptionally high rate of exports of heavy plant. There is a feeling that it is not sound policy to deprive British industry of an adequate supply of electricity by exporting too large a proportion of generating plant. This is accomplished by the reflection that we are equipping our potential competitors in the international field for a struggle which may come at a time when our own industries are at a comparative disadvantage, owing to a lack of generating capacity and electrical equipment."

Lord Citrine expressed the opinion that economic self-sufficiency for Great Britain by the time of the end of the Marshall plan in 1952 is probably dependent as much upon the extent to which generating capacity can be increased as upon any other single factor.

William Lloyd, Stoker Engineer, Dies

William Lloyd, widely known stoker designer and consultant on stoker engineering for Combustion Engineering-Superheater, Inc., died in New York on Aug. 7, following a brief illness. He was 82 years old, but had regularly attended his office until a few days before his death.

Associated with the commercial development and widespread application of the Coxe traveling grate stoker for more than forty years, he was largely responsible for its present outstanding position in industry with nearly 2600 installations.

Mr. Lloyd was born in Wales and was brought to this country by his parents who settled in the anthracite region of Pennsylvania. When nine years old,

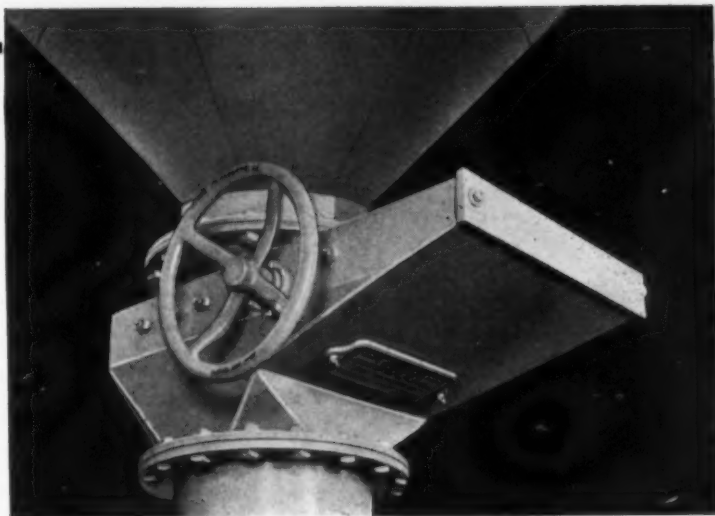
following his father's death, he went to work in the collieries as a slate picker. At 17, he began a machinist apprenticeship with Vulcan Iron Works and became superintendent of one of its shops at 23. In 1906, he was made manager of the Drifton, Pa., shops of the Lehigh Valley Coal Company where the Coxe traveling grate stoker had been under development by Eckley B. Coxe, who had died several



years previous. Mr. Lloyd redesigned the stoker in 1910.

The Coxe Traveling Grate Company was organized in 1914, with Mr. Lloyd as president, and when this company was purchased by Combustion Engineering in 1917, he continued with the latter company and later brought out the Lloyd stoker.

He was a member of the A.S.M.E., and is survived by two sons, Grier and Menzo, two brothers and several grandchildren.



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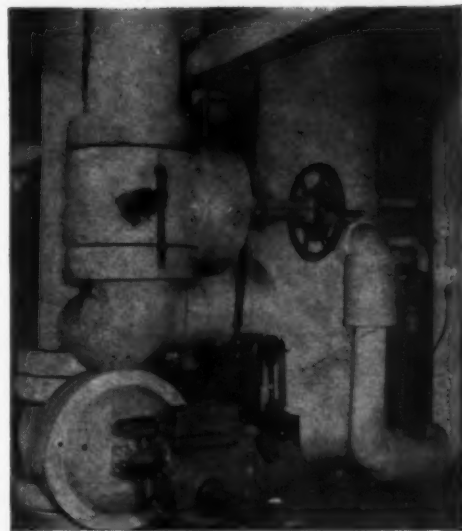
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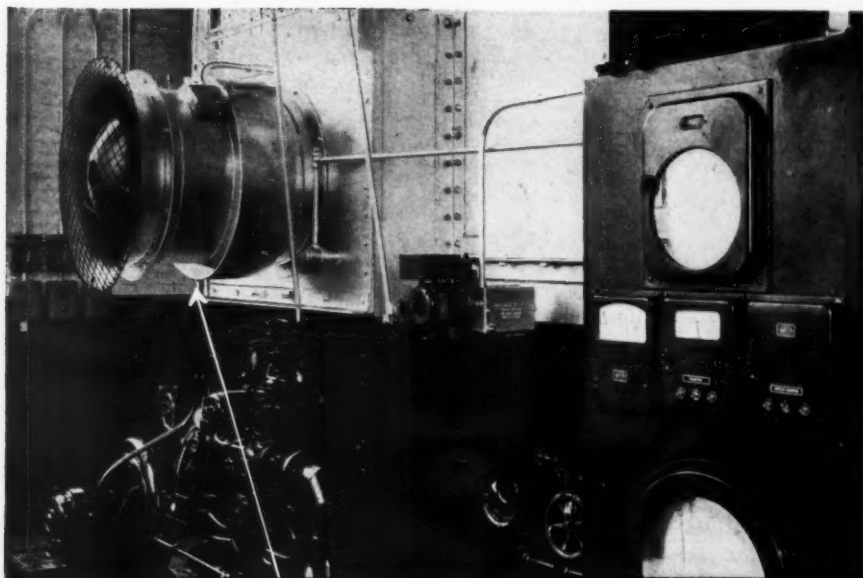


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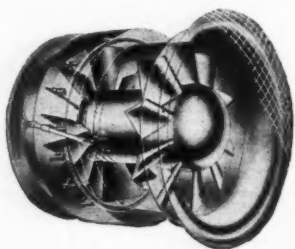
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